Control
ENGINEERING
INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication
Two Dollars
SEPTEMBER 1960

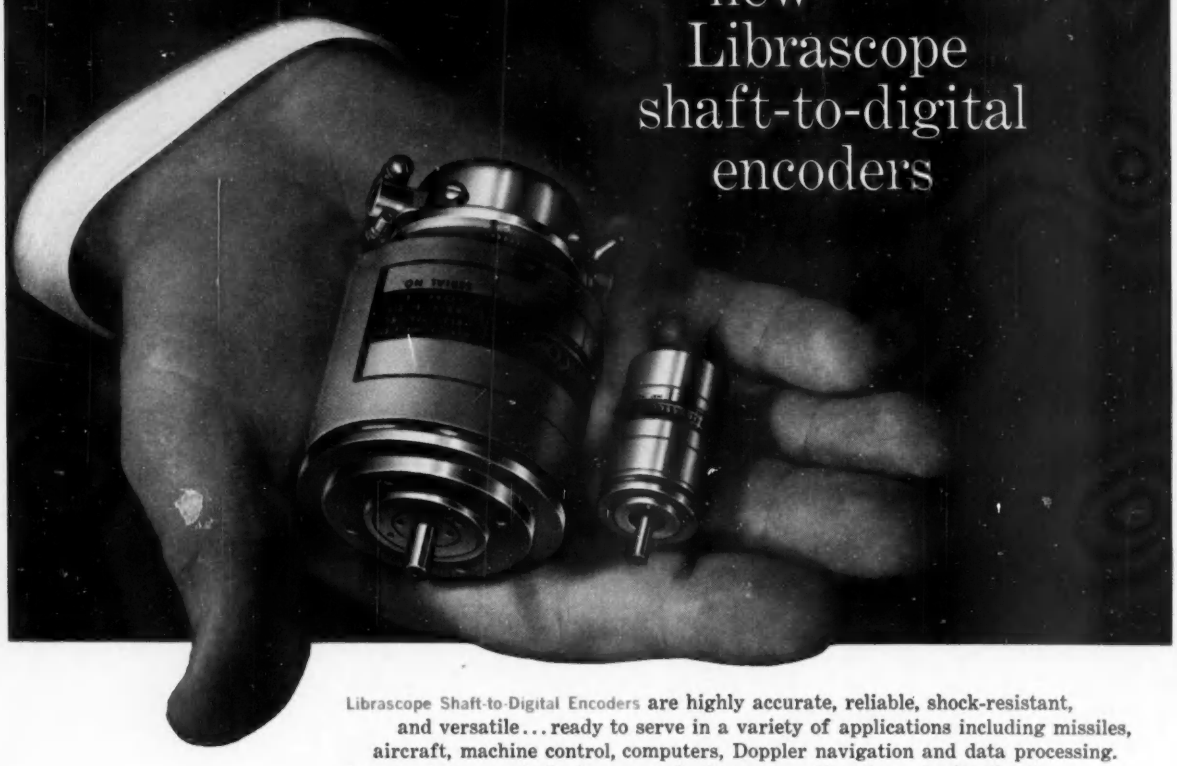
INDUSTRIAL AUTOMATIC SYSTEMS

Progress and Payout

17 case studies show control at work across industry

NO OTHER LINE SO COMPLETE · 38 NEW ENCODERS · MAG
CODERS · 38 NEW ENCODER MODELS · SIZE 8 ENCODERS ·
LINE SO COMPLETE · MAGNETIC ENCODERS · 38 NEW ENC
ODERS · SINE/COSINE ENCODERS · GRAY ENCODERS · 38 N
SELF-DECODING ENCODERS · NO OTHER LINE SO COMPLE

new Librascope shaft-to-digital encoders



Librascope Shaft-to-Digital Encoders **are highly accurate, reliable, shock-resistant, and versatile... ready to serve in a variety of applications including missiles, aircraft, machine control, computers, Doppler navigation and data processing.** Accuracy that counts **is the by-word of a Librascope Encoder... backed by the superior technology and reputation of one of the world's largest producers of** *Computers that Pace Man's Expanding Mind.*

new noncontact magnetic encoder

MODEL NO. 807

FEATURES:
Long life, high reliability, high speed, natural binary V-Scan readout.

SPECIFICATIONS:
Output Code: natural binary
Resolution: (per input shaft turn) 128 counts
Full Scale Capacity: 7 bits*
Speed: operating from 0 to 10,000 rpm
Life Expectancy: 20,000 hours at 4,000 rpm; 4 x 10^9 revolutions
Starting Torque: 0.1 in-oz. max.
Diameter: 2"
Length: 1 13/16"
Weight: 5 ounces

*ALSO AVAILABLE IN 13, 17, AND 19 BIT CAPACITIES.

new subminiature size 8 encoder

MODEL NOS. 787 & 793

FEATURES:
Low torque, low inertia, long life, high reliability, withstands severe environments.

SPECIFICATIONS:
Output Code: natural binary
Resolution: (per input shaft turn) 128 counts
Full Scale Capacity: 7 bits, 13 bits
Speed: operating 200 rpm, slew 600 rpm
Life Expectancy: 2 x 10^6 revolutions at 200 rpm
Starting Torque: 0.5 oz-in. maximum
Diameter: .750"
Weight: 3 ounces

other popular Librascope encoders

Code	Model no.	Full scale capacity	Resolution per input shaft turn
Binary	773	13 bits	128 counts
	0-773	oil-filled unit for increased life	
Binary	710	10 bits	1024 counts
Binary	707 (707D*)	7 bits	128 "
	713 (713D*)	13 bits	128 "
	717 (717D*)	17 bits	128 "
	719 (719D*)	19 bits	128 "
	0-713	oil-filled unit for increased life	
Self-Decoding Binary	740	10 bits	1024 counts
B/C/D	723 (723D*)	2,000 counts	200 "
	724 (724D*)	20,000 "	200 "
	733 (733D*)	3,600 "	200 "
	734 (734D*)	36,000 "	200 "
	735	360,000 "	200 "
Sine/Cosine	757-S**	4 quadrants per turn	7 bits per quadrant + limit 1
	758 758-S**	4 quadrants per turn	8 bits per quadrant + limit 1
Gray	708	8 bits	256 counts

*Contain isolation diodes for multiplexing

**Servo driven, hermetically sealed

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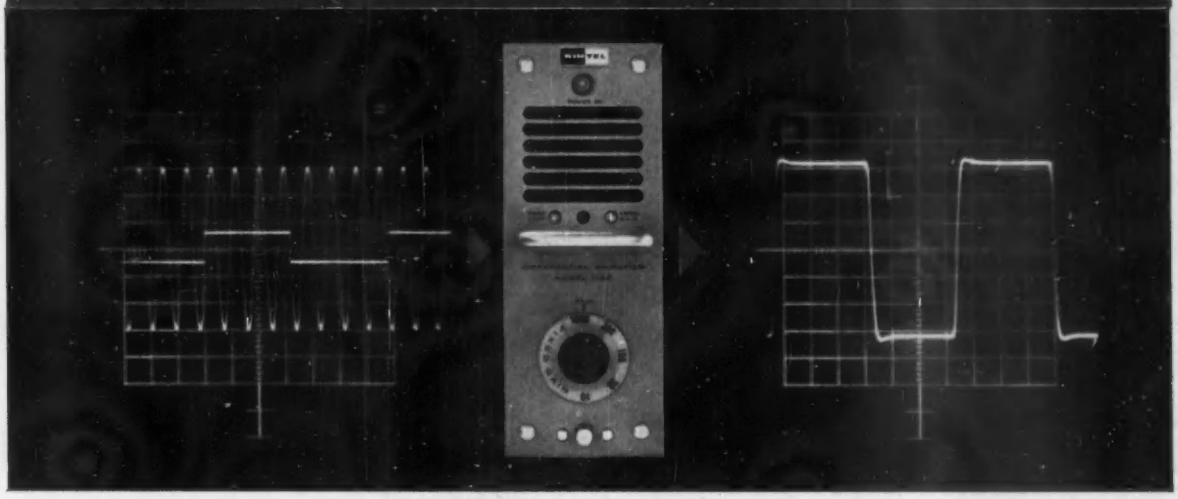
CIRCLE 132 ON READER SERVICE CARD

(picture of a KIN TEL differential amplifier at work)

6 volts of 60~ common-mode noise and 6 millivolts of signal in here

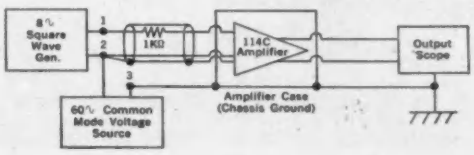
2 microvolts of 60~ noise (equivalent input) and 6 volts of signal out here



If you measure the output of thermocouples, and the thermocouples are bonded to a rocket engine or almost any other grounded object, and the distance between thermocouples and amplifiers is more than a few feet, you should consider the above illustration carefully. While we'll admit your thermocouples probably aren't producing square waves, nine chances out of ten you *do* have a problem with 60-cycle common-mode noise. Nearly everybody does.

What can be done about it? Well, KIN TEL differential amplifiers reject ruinous 60-cycle common-mode hum and noise by a factor of 3,000,000 to 1 with any unbalance up to 1000 ohms in series with either side of the input, 1,000,000 to 1 with 10,000 ohms unbalance. Rejection for DC is practically infinite and both input and output can be floated up to ±300 volts DC or peak AC. The secret of this exceptionally high common-mode rejection in the presence of high input unbalance is isolation. Input signal terminals are isolated from chassis ground by 10,000,000 megohms and 0.6 micromicrofarads. Input and output signal terminals are completely isolated from each other. Output signal terminals are isolated from ground to almost the same extent as the input. With this virtually perfect isolation, you can rescue microvolt level signals from volts of common-mode noise, regardless of whether load and transducer are floating or grounded, balanced or unbalanced.

Before you send us that letter... the input scope photo is a double exposure. The square wave input signal was taken with the scope connected across points 1 and 2 (see drawing below) with 5 mv/division sensitivity. To show the noise, the scope was connected between points 2 and 3, and sensitivity was 1 v/division. The scope on the output was set for 1 v/division sensitivity and, of course, no noise is evident.



Specifications other than common-mode rejection are equally impressive. Linearity is 0.01% of full scale (10 volt) output for either polarity, 0.02% of full scale for plus-to-minus or minus-to-plus polarities. Equivalent input drift is less than 2μv; noise at full amplifier bandwidth is less than 6μv. Input impedance is 30 megohms, output impedance less than 0.25 ohms. Standard bandwidth is less than 3 db down at 80 cps, and the amplifier settles to within 99.9% of final value within 50 milliseconds for an output change of 5 volts. Plug-in input and output filters allow bandwidth options from 3 cps to 120 cps, transient response as good as 25 milliseconds. Gain is 10 to 1000 in 5 steps. A front panel vernier control provides 1 to greater than 3.3 times continuous adjustment of each gain step. Gain stability is ±0.05%. Output capability is 10 volts at 10 milliamps. Amplifiers have integral power supplies. Enclosures include six-amplifier and single-amplifier 19-inch rack modules, and portable single amplifier cabinets.

To meet your exact requirements at minimum cost, two models are now available: the 114A at $775, and the 114C (described) at $875. Delivery on both models is currently from stock. Write for detailed technical data or a demonstration. Engineering representatives in all major cities.

KIN TEL
A DIVISION OF
COHU
ELECTRONICS, INC.

5725 Kearny Villa Road, San Diego 11, California
Phone: BRowning 7-6700

NEW

E-W Time Code Generator

Model 6190

...Makes time with Atomic Accuracy

Solid State EW Timing Code Generator Uses Atomchron Input

Epsco-West's new Model 6190 Time Code Generator is accurate, flexible, and reliable. In conformance with recommendations of the Interrange Instrument Group (IRIG), the Model 6190 generates a 36 bit 100 pps code, a 28 bit 2 pps code and a 20 bit 1 ppm code. Other outputs are available to drive digital printers, digital tape recorders, strip-chart recorders, oscillograph galvanometers, synchronizing signals and mixed tones of precision frequencies.

The EW Model 6190 is one of a complete line of solid state, modular time code equipment which includes time code generators, time code translators, timing terminals, and universal tape search equipment.

Complete technical information on the Model 6190 Time Code Generator is ready now. Call your nearby knowledgeable Epsco-West engineering representative or address Dept. 21.

Advanced Circuitry Stems From Transistor Know-How

In the Model 6190, all pulse widths and timing are directly derived from the digital dividers and time accumulator by diode matrices. No one-shot circuits are used. Information is not transferred from one register to another. No "stub" counter chains are used. These design features provide absolute synchronism and minimum distortion. Modulation occurs precisely at the true positive going zero-axis point on the carrier.

Epsco-West
First in Data Control

A Division of EPSCO Inc., Cambridge, Mass.

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7

KEY SPECIFICATIONS

Input Signal

100 kc, 1-volt RMS, to impedance of 10,000 ohms. An internal frequency standard may be supplied as optional equipment.

Outputs

1. Logic Output, 36-bit parallel BCD (—12v for binary "zero", 0-volts for binary "one").
2. 20-bit, 1 ppm on 100 cps carrier, 1 hour time frame.
3. 28-bit, 2 pps on 100 cps carrier, 1 minute time frame.
4. 36-bit, 100 pps on 1000 cps carrier, 1 second time frame.
5. Three outputs of the 100 pps, 2 pps and 1 ppm modulation pulses at 2 milliampere max. for driving galvanometers.
6. Relay closure at 1 ppm, 28-bit, 2 pps code, closure for pulse durations.
7. 1 pps at 1-volt, synch pulse, accessible front and rear.
8. 1 pps relay closure of 200 ms.
9. Mixed tones output; 100kc, 50kc, 25kc, 12.5kc, 6.25kc, 3.125kc sine waves.

Elapsed-Time Range

399 days 23 hr. 59 min. 59 sec.

Accuracy

Dependent only on reference oscillator.

Size

19" wide by 10½" high x 18" deep.

Control ENGINEERING

SEPTEMBER 1960
VOL. 7 NO. 9

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

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CONTROL ENGINEERING, September 1960, Vol 7, No. 9. Published monthly by McGraw-Hill Publishing Co., Inc., 330 W. 42nd St., New York 36, N. Y. Publication Office: 99 N. Broadway, Albany 1, N. Y. Second-class postage paid at Albany, N. Y. U. S. Subscription: $3 per year. Further details, p. 6.

a new look in counters

AND NEW RELIABILITY, TOO

CMC was first to introduce the all-transistor 10 megacycle counter. Now CMC scores another important first with its complete new line of vacuum tube counting, timing and frequency measuring equipment. Note the clean, functional lines of these tastefully styled instruments... user engineered to eliminate costly "cockpit trouble". These instruments are the most reliable vacuum tube counters ever built. In the counter-timer below, for example, nine tubes have been eliminated. New modular circuitry simplifies maintenance and reduces weight. Unitized construction is exceptionally rugged. And to further simplify matters, all models have three key components in common—input amplifiers, power supplies, and shaping circuits. In short, these instruments will give you long, trouble-free operation.

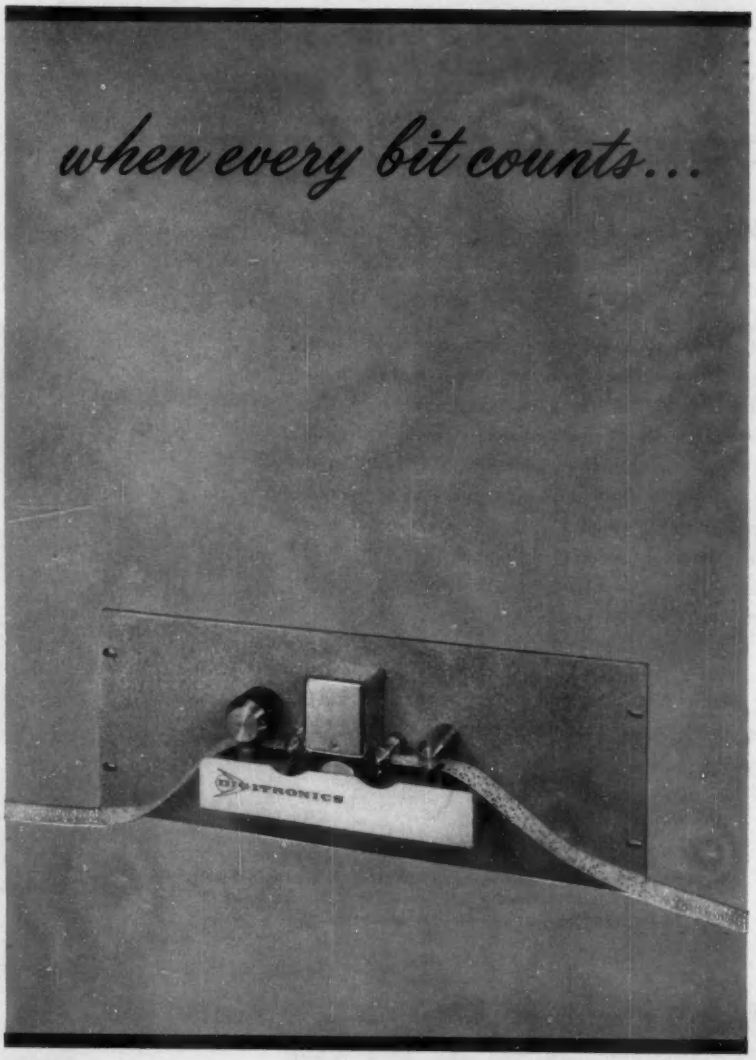
BUT SEEING IS BELIEVING—Your nearby CMC engineering representative will be happy to arrange a demonstration and provide complete technical data. Or you can write us direct. *Please Address Dept.* 21.

CMC's Model 226B Universal Counter-Timer (1 mc) leads a complete new line which includes a 220 kc universal counter-timer, a time interval meter and a frequency-period meter.

PRICES:
Model 226B, $1175; Model 226BN, illustrated, $1445 with Nixies; Model 225C, $900; Model 203B, $995; Model 251B, $915. Rack mount $10 extra. F.O.B. Sylmar, California.

Computer Measurements Co.
A Division of Pacific Industries
12970 Bradley Avenue, Sylmar, California
Phone: EMpire 7-2161

CIRCLE 5 ON READER SERVICE CARD



DYKOR® HIGH SPEED PERFORATED TAPE READER

This completely transistorized photo-electric unit is the utmost in reading reliability. At 1000 characters per second it stops before the next character...reads any standard tape including 40% transmissive paper, and handles 5 to 8-level tapes interchangeably. Outputs are compatible with either PNP or NPN transistor circuits.

The user may select single or dual speeds, 10½" reel models or 8" spooler accessories.

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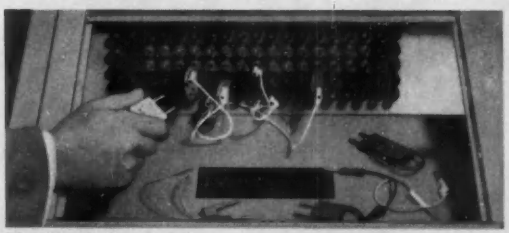
ABC | ABP

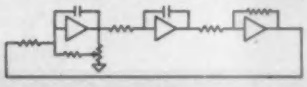
Did you ever use a computer as versatile as the DONNER 3100?

The Donner 3100 isn't for people who merely wish to push buttons. It is a medium sized, high accuracy computer, simple to operate, but designed so it doesn't horsecollar the operator. In its class (20 to 100 amplifiers) it is the most versatile analog computer. Two big reasons for this are the 3100's *uncommitted amplifiers* and its *simulation board*, an auxiliary patchbay electrically connected to the main removable problem board. Here's what they do:

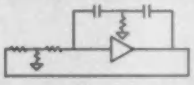
Uncommitted Amplifiers. The 3100's amplifiers are not already wired as summers or integrators. The operator patches his resistors and capacitors to the amplifier. Obviously, he is not limited to using computing components with fixed values. If he wants to use only two components per amplifier, all the rest are free. Depending upon your needs, the 3100 can be supplied with up to 50 amplifiers per console and two or more consoles may be slaved.



The Simulation Board. Here the operator can plug in a wide variety of components—resistors, capacitors, pots and diodes. He can synthesize (a) complex input and feedback networks for amplifiers, (b) complex resistor-diode limiting circuits and (c) resistor-capacitor-inductor filter networks. Programming these circuits on the simulation board is far simpler and saves amplifiers. For example, a mass-spring system is oscillatory and usually needs three amplifiers to simulate it:



But this clever little circuit does the same thing:



You see, we have eliminated two amplifiers by using the simulation board.

Speaking of economy, **$13,995** buys a Donner 3100 with 30 stabilized amplifiers and 55 potentiometers. A full line of nonlinear and accessory equipment is available. Free instruction on computer theory and operation is included.

Get More Facts — *Contact your Donner engineering representative for Data File 310, or write directly to Dept. 21.*

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29

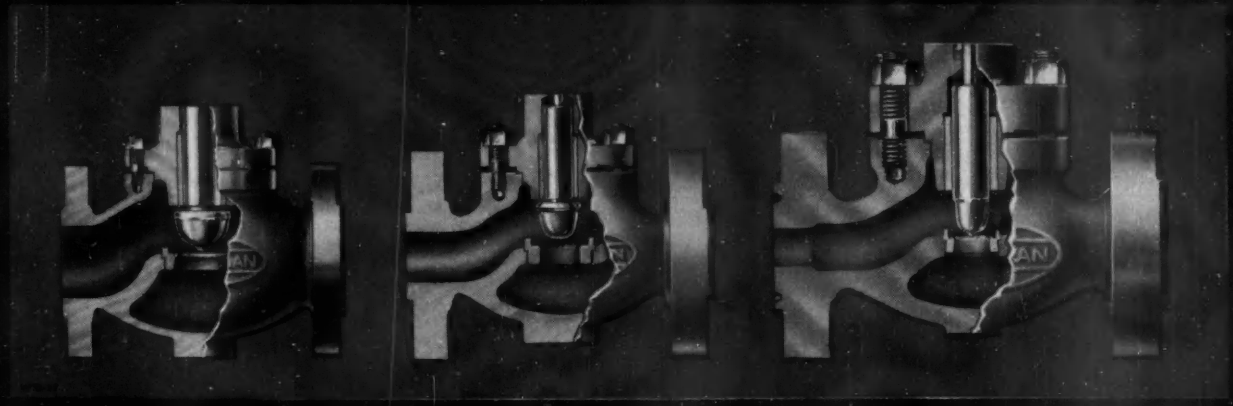
Versatility

is the word for these

SINGLE SEATED CONTROL VALVES

- **High Capacity**
- **High Allowable Pressure Drops**
- **Wide Selection of Reduced Capacity Trim**

The new line of Mason-Neilan 20000 Series Control Valves provides the most versatile single seat design available. They have an unusual combination of premium features that suit them for a wide range of applications, including viscous fluids and slurries.



Two inch, 600 lb. body with full capacity plug Two inch, 1500 lb. body with full capacity plug Two inch, 2500 lb. body with full capacity plug

See Masoneilan Exhibit at the

High Capacity . . . top guiding, unrestricted seat ring area, body and plug contours provide greater capacity than most top-and-bottom-guided double seated valves of comparable sizes.

High Pressures and Pressure Drops . . . high capacity is attained with minimum seat ring areas, resulting in less unbalance force, permitting higher pressure drops. Heavy guiding throughout full stroke results in a minimum of unsupported plug length and allows high pressure and high pressure drop applications without lateral vibration. Generous guide surfaces and large plug stems are sized in accordance with body rating.

Soft Seat Trim . . . available in Teflon and Buna-N. Suitable for static pressures and pressure drops up to 500 psi.

Wide Selection of Reduced Capacity Trim . . . for those applications where velocity due to high drop is a consideration (or where future requirements for larger capacity are a factor) a wide selection of reduced capacity trim is available — and interchangeable in comparable valve sizes and ratings (see table). The proper relationship between stroke and trim size is maintained in order to provide the strongest possible plug tip, particularly in hard, brittle materials.

Wide Selection of Materials . . . the design of body and plug permits the use of suitable special materials to meet severe operating conditions.

Suitable for Slurries . . . body and plug contours (plus the fact that no bottom guiding is required) make these valves suitable for viscous fluids and slurries.

Welding Ends Available . . . the solid-cast body allows the use of welding ends. The removable bolted bonnet permits easy (only one joint to break) inspection or cleaning with valve in the line.

Actuators Sized to Body Rating . . . the standard spring-diaphragm (direct or reverse) actuator is sized according to body rating, thus minimizing requirements for oversize actuators in severe applications.

These 20000 Series are economical to buy and operate. Look into these many advantages; send for complete details or contact your local Mason-Neilan representative.

MASONEILAN

MASON-NEILAN

Division of Worthington Corporation

53 NAHATAN STREET, NORWOOD, MASS., U.S.A.

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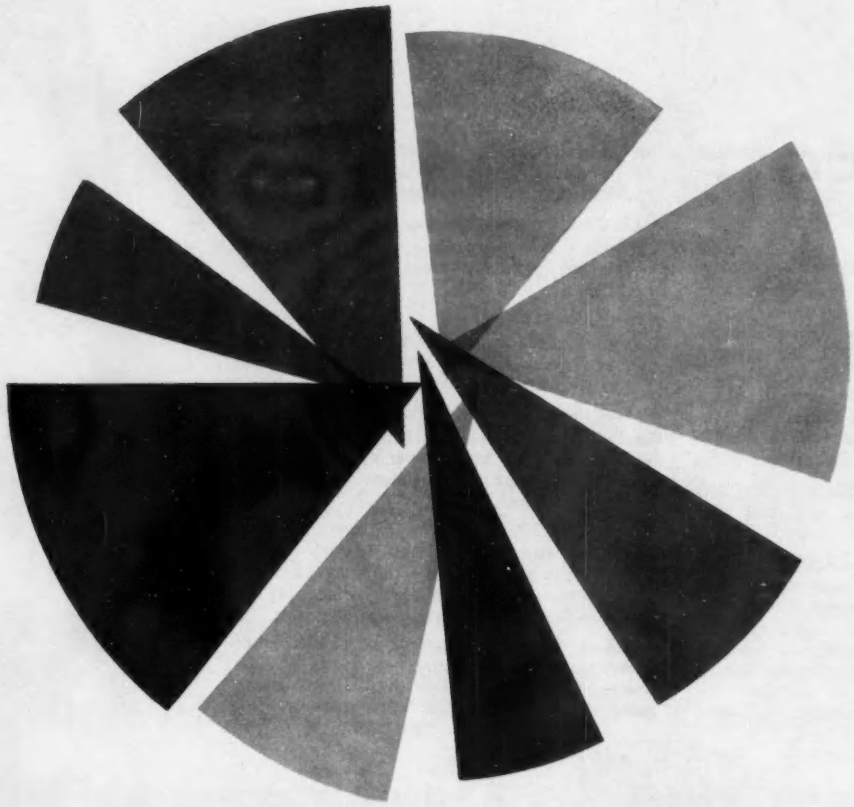
In Canada: Worthington (Canada) Ltd., Mason-Neilan Division

Available Cv Ratings

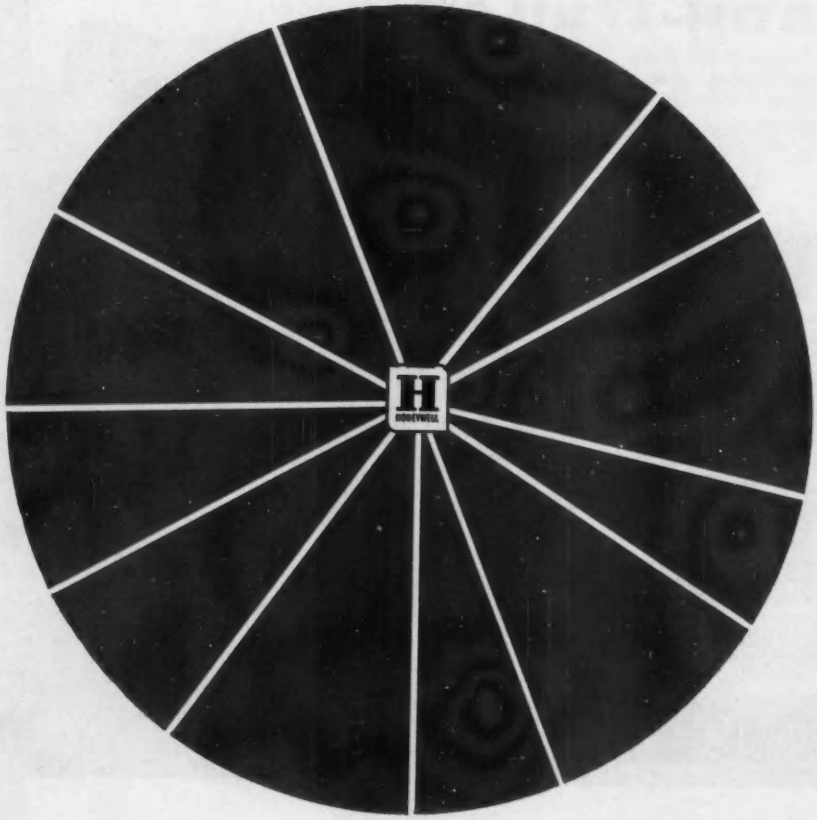
Valve Size	NOMINAL TRIM SIZE											
	¼"	⅜"	½"	¾"	1"	1½"	2"	3"	4"	6"	8"	10"
¾"	1.5	3.4	5.2	8								
1"	1.5	3.4	5.2	10.8	12							
1½"	1.5	3.4	5.2	12	14	25						
2"	1.5	3.4	5.2	12	18	25	46					
3"				12		25	46	110				
4"						25	46	110	195			
6"							46	110	195	400		
8"								110	195	400	640	
10"									195	400	640	1000

I.S.A. Show, Booth 1412

CIRCLE 9 ON READER SERVICE CARD



YOUR PLANT'S CONTROL SYSTEM—HYBRID OR HONEYWELL?



The answer can be important to you. True, you can combine several makes of instruments into a system and get adequate results. But you usually pay a penalty for hybrid systems. There's the burden of responsibility for engineering and maintaining the system. There's the question of whether it will do what you want it to. There's the problem of modifying various makes of components to work together. And there's the inconvenience of buying instruments and spare parts from several suppliers instead of one.

Single-Source Responsibility. You avoid all of this with an all-Honeywell data processing or automatic control system. All components, from primary measuring elements to final controls, are supplied by Honeywell. If your requirements call for an analog or digital computer, Honeywell can supply it. From our systems engineers you get the advantage of experience gathered over 75 years of measurement and control work in scientific, military and industrial operations. And Honeywell takes full responsibility for the system, from initial planning through installation and startup, and even including maintenance.

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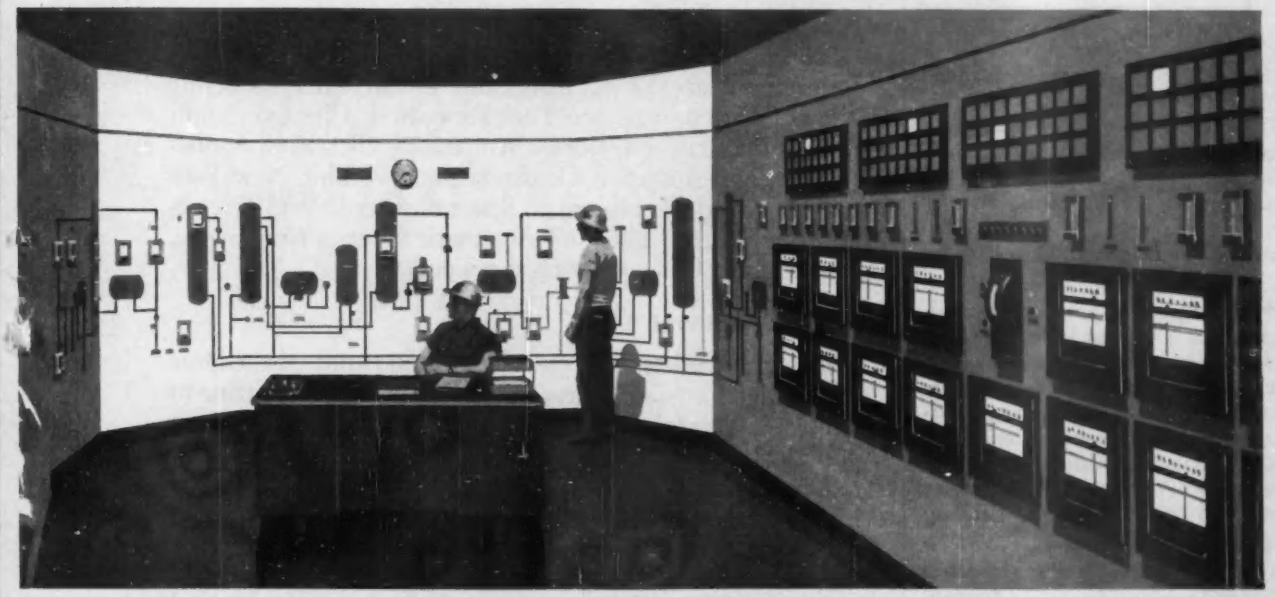
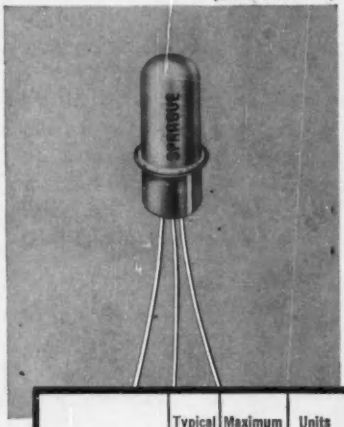


Type 2N501 Super High-Speed Micro-Alloy Diffused-Base Transistors

(2 X Actual Size)



	Typical	Maximum	Units
Rise Time (t_r)	9	18	mμsec
Storage Time (t_s)	9	12	mμsec
Fall Time (t_f)	7	10	mμsec

In circuit with current gain of 10 and voltage turn off.

Unexcelled for super high-speed computer applications, Sprague's Type 2N501 Micro-Alloy Transistors combine high gain and high frequency response with unusual stability and high operation efficiency even under severe environmental conditions and life tests.

Sprague's mechanized electrochemical process permits the fabrication of a graded base transistor with no intrinsic base region. The Type 2N501 can thus maintain its super high-speed switching characteristics right down to its saturation voltage, providing all the advantages of direct-coupled circuitry with no impairment of switching speeds.

Write for complete engineering data to Technical Literature Section, Sprague Electric Company, 407 Marshall Street, North Adams, Mass.

SHOPTALK

Guide to tool show

Make sure that if you're going to the Production Engineering and Machine Tool Shows you don't miss the opportunity presented by John Cooney's article on page 158 of this issue. John's preshow visits to over 50 machine tool builders gave him a detailed view of what's new in machine control. He passes this view along in his 16-page special report, "Automatic Metalworking—a Status Report". Tear it out and carry it with you and you'll be able to find most of the new numerical control systems and other automatic machines without hunting for them.

Quiet: staff at work

When the feature portion of this issue was completed and we started looking at it upsidedown and backwards to make sure that it satisfied the editors, we discovered to our surprise that half of it (33 of 67 feature pages) was totally staff written, and that another 11 pages were generated from raw reports, proposals, etc. originally prepared by busy engineers who didn't have the time to put the material in even rough article form. All this shows two things: 1) Often there is no one authority that can supply all the facts for an article, our editors must gather information from many sources; and 2) If CtE is going to continue to supply you with descriptions of the latest and most advanced in the control field, many of the articles are going to have to be written from interviews, rough sketches, raw reports, etc.

Busy month for control engineers

September is always a full month for control engineers, but this one wins a prize with major technical meetings and shows for every segment of our readership: Production Engineering Show, Chicago; Machine Tool Exposition, Chicago; Ninth Annual Industrial Electronics Symposium, Cleveland; Annual Instrument-Automation Conference and Exhibit, New York City; National Symposium on Space Electronics and Telemetry, Washington; and Joint Automatic Control Conference, Cambridge. Get your track shoes on.

Article retrieval

Like the readers of CONTROL ENGINEERING, the editors frequently must search through past issues of the magazine to find when a certain item was published or what articles were published on a certain subject. To handle this information retrieval problem we simply tear out the contents page of each issue and file them in order, adding the annual index each December. This way it only takes a few minutes to scan the subject matter for several years right up to date. And if you tear out and file articles, you can indicate how you classified the article on the contents page right next to the title.

Tung-Sol high power germanium transistors

2N174, 2N174A, 2N173, 2N278, 2N277, 2N443, 2N442, 2N441, TS748*

This full and select complement of Tung-Sol high power transistors offers many distinct advantages over similar competitive types.

- Exclusive design features combine with Tung-Sol's pace-setting quality assurance practises to assure designers unexcelled operational reliability.
- Wide interchangeability lets you specify these pnp transistors for most industrial and military uses. Typical applications include high power amplifiers, DC-to-DC converters, DC-to-AC inverters, regulated power supplies, motor controls, servo amplifiers, relay drivers, switching circuits, etc.
- Every transistor in this versatile series produces highly efficient power transfer and audio amplification.
- They feature the vacuum-tight, all copper "Cold Weld" package—a Tung-Sol "first" in this transistor class—for broader design flexibility and long-life reliability.
- They are manufactured in the industry-preferred JEDEC-TO-36 case. This stud-mounted single-end construction with solid-lug terminals simplifies installation and facilitates efficient heat-sink design.
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Absolute Maximum Ratings @ 25°C	2N174A	2N174	2N173	2N443	2N278	2N442	2N277	2N441	
Collector Voltage BV_{CB} (V_{EB} = +1.5v)	80	80	60	60	50	50	40	40	Volts
Collector Voltage BV_{CES} (I_C = 0.3A)	70	70	50	50	45	45	40	40	Volts
Emitter Voltage BV_{EBO}	60	60	40	40	30	30	20	20	Volts
Collector Current I_C	15	15	15	15	15	15	15	15	Amp
Junction Temperature T_j	−55 to +95	−55 to +95	−55 to +95	−55 to +95	−55 to +95	−55 to +95	−55 to +95	−55 to +95	°C

*The TS748 is specially designed to meet the requirements of MIL-T-19500/13A and is supplied with flexible leads.

...deliver up to 15 amperes

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TUNG-SOL

It's Foxboro Consotrols

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†Completely integrated Sohio Toledo unit has a refining capacity of 60,000 bbls. per day. The 13-acre facility requires only 17 operators per shift—was designed and built by the M. W. Kellogg Company.

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If you're not already familiar with the Consotrol story ask your nearby Foxboro field engineer for full details. Or write Foxboro for Bulletin 13-18. The Foxboro Company, 859 Neponset Avenue, Foxboro, Massachusetts. *Reg. U.S. Pat. Off.*

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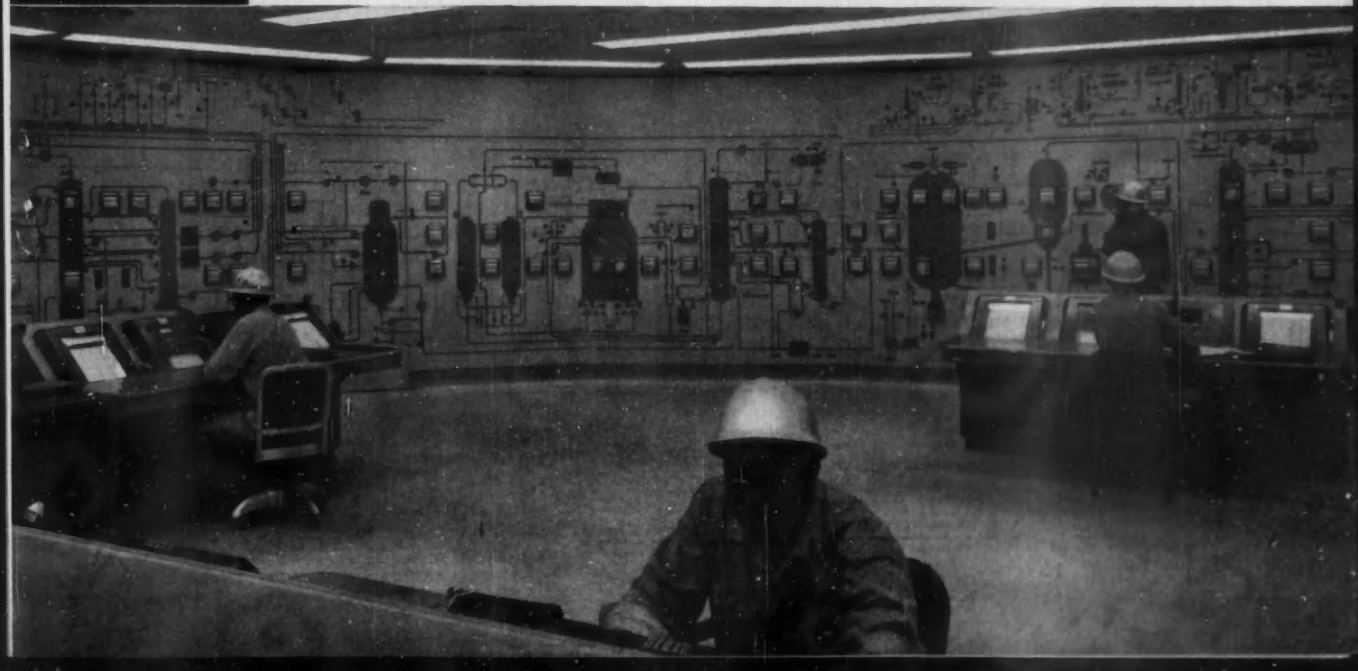
↓Nerve center at Toledo is this 96-ft. Foxboro-instrumented control panel. Six "satellite" panels handle local control. Since unit must work as one continuous operation—or not at all—reliable instrument performance is essential.



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Avoid costly production loss and complicated restart caused by unscheduled "down-time" by applying Texas Instruments semiconductors and components to *your* industrial control system. Now, TI offers you a complete line of high-reliability devices *specifically* designed to meet the exacting demands of your industrial control applications.

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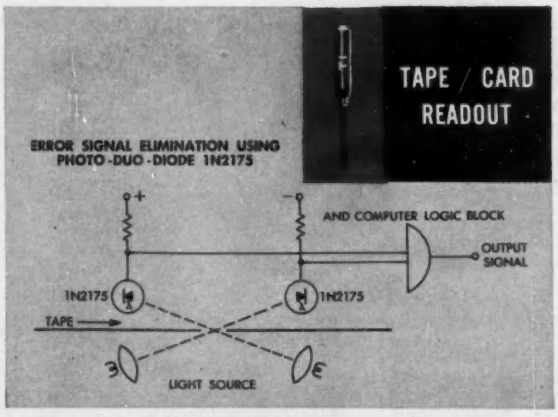
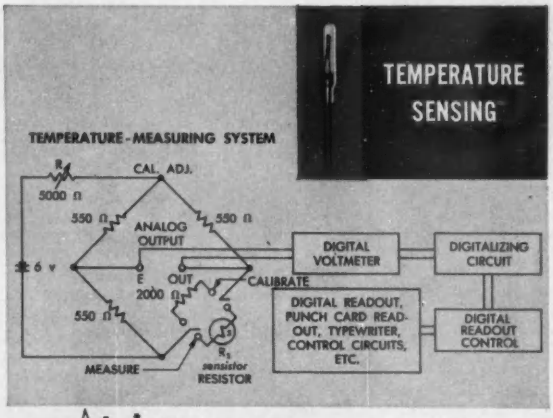
Write today on your company letterhead to TI's team of highly qualified industrial design applications engineers for expert assistance in meeting your specific control system requirements.



TI 1N2175 photo-duo-diodes Four times more sensitive than any other commercially available photosensitive unit, the new TI PHOTO-DUO-DIODE is ideal for your industrial control tape readout, inspection, counting, switching, interlocking, and over-load protection applications. This new light sensing device passes up to 1200 microamps when exposed to 1200 foot-candles of light and less than 0.5 microamps in darkness. Rated at 250 milliwatts dissipation at 25°C, the TI 1N2175 will operate equally well on either alternating or direct current and any biasing voltage up to 50 volts.



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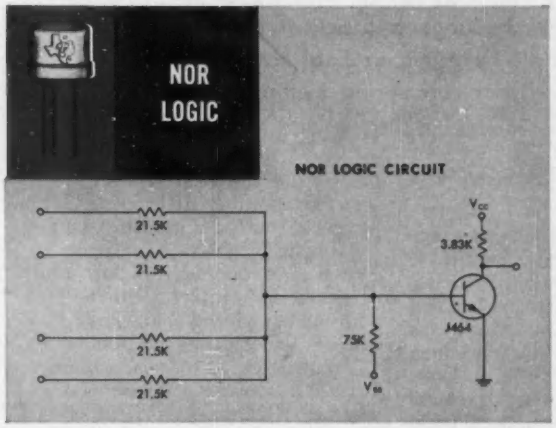

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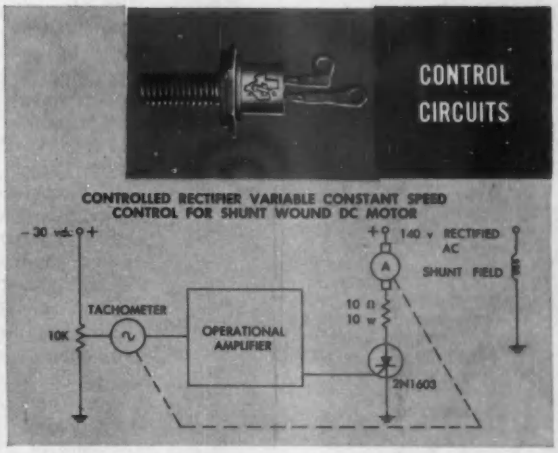
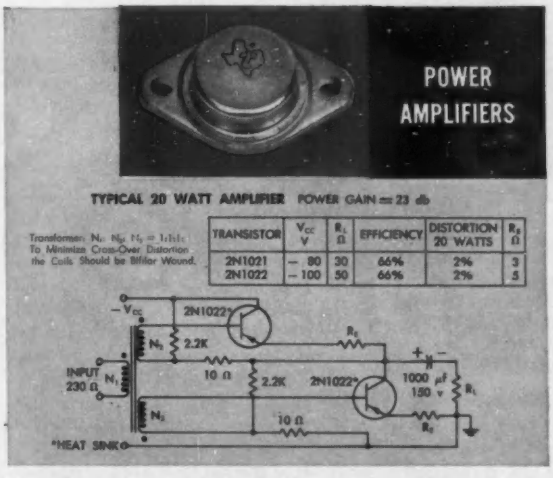


TI pnpn silicon controlled rectifiers Apply the triggering and firing function of TI PNPN Silicon controlled rectifiers to your system to replace thyratron tubes, relays and magnetic amplifiers and gain over-all increased system reliability. Put this ruggedly packaged rectifier in use today in your regulated power supplies, servo motor control circuits, static switching circuits and as a protective device in power output circuits.



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TI APPLICATION NOTES

Write TODAY on your company letterhead for TI Application Notes pertaining to transistorization for industrial control systems. Address your inquiry to: Mr. Bruce Williams, Industrial Applications, P. O. Box 312, Dallas, Texas.

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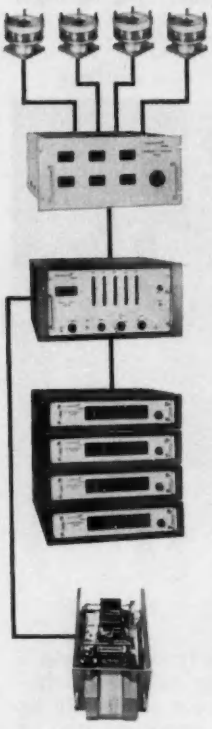

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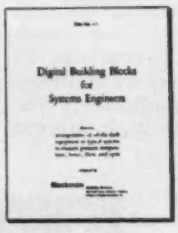

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FEEDBACK

HOW TO DO IT

A reader describes a practical method of converting binary and decimal notations—by a dividing and conquering method.

A handy kink

TO THE EDITOR—

When the electronics engineer ventures (or is pushed) into the area of computers and digital control systems, he finds familiar components handled in ways new to him. Eventually his vocabulary grows to include such terminology as flip-flop, NOR logic, accumulator, storage register, memory cores, etc., and his mathematical background enlarges to include the methods of binary arithmetic. At first the long strings of 1's and 0's of the binary number system seem strange and awkward to handle, but this unfamiliarity gradually vanishes as the engineer becomes intimate with binary notation. The conversion of decimal to binary numbers, however, as well as the conversion of binary to decimal numbers remains a tedious, tiresome, and time-consuming task. Here is a relatively painless conversion method.

A decimal number can be converted to its binary equivalent by successively halving the number, writing down a 1 when the result is an odd number and a 0 when the result is even. The collection of 1's and 0's obtained in this manner is the binary equivalent of the original decimal number. This technique is illustrated in Figure 1.

(A)		1	2	5	10	20				
(B)		1	2	5	10	20				
		1	0	1	0	0				
(C)	1	2	5	10	20	40	81	163	326	652
	1	0	1	0	0	0	1	1	0	0

FIG. 1. Conversion of decimal to binary notation by the process of repeated halving of the decimal number. Binary equivalent is now determined by substituting 1's for the odd numbers and 0's for the even numbers.

It is assumed here that the binary representation of decimal number 20 is to be found. The 20 is written down and then halved; the result (10) is then written to the left of the 20. The 10 is now halved and the result (5) is written to the left. Any fractions that develop during the halving process are dropped. Halving of 5 therefore yields a result of 2. This process is continued until the number 1 is reached, as shown in Figure 1A. The binary equivalent is now easily determined by writing a 1 under each odd number (1 and 5 in Figure 1B), and a 0 under each even number (2, 10, and 20). This binary number, 10100, is equivalent to decimal 20. The same technique can, of course, be used for larger numbers. As illustrated in 1C, decimal 652 is converted to binary 1010001100.

A quantity expressed in binary notation can be converted to its decimal system equivalent by the inverse of the process illustrated in Figure 1. As shown in Figure 2A, a 1 is written over the first bit and a 2 is written over the next bit, in Figure 2B. The 2 is now doubled and the result (4) written over the next bit as shown at C in Figure 2. Since an odd number must appear above each 1 in the binary number, the number obtained in the doubling process is increased by one each time a binary 1 is encountered. For this reason the number 9 rather than 8 appears at D in Figure 2. This process is continued, and the number which appears above the rightmost bit is the decimal system equivalent. As shown at E in Figure 2, binary 1001010 is converted to decimal equivalent 74.

(A)	1						
	1	0	0	1	0	1	0
(B)	1	2					
	1	0	0	1	0	1	0
(C)	1	2	4				
	1	0	0	1	0	1	0
(D)	1	2	4	9			
	1	0	0	1	0	1	0
(E)	1	2	4	9	18	37	74
	1	0	0	1	0	1	0

FIG. 2. Conversion of binary to decimal notation by the process of repeated doubling. Odd numbers are written above the 1's and even numbers above the 0's.

With a little practice, one becomes proficient in the use of these methods,

The Offner Type R All Transistor Dynograph

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RP TWO CHANNEL
Compact, economical, convenient where only one or two channels are desired.

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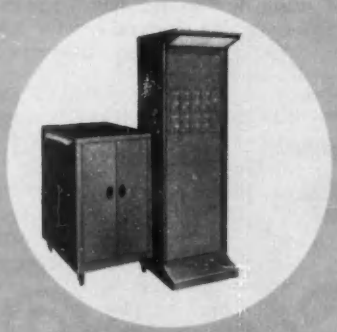
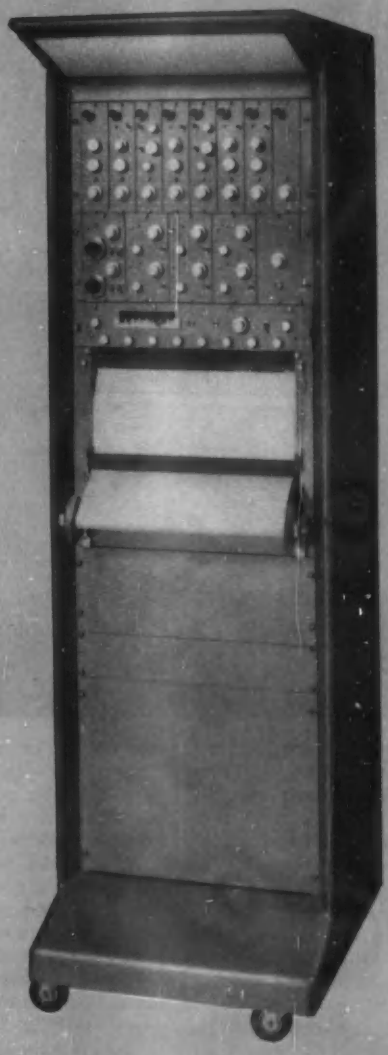
Features horizontal paper travel. Available as Type R or RC.



R SIXTEEN CHANNEL
Assemblies with 16 channels. 24 inch paper permits up to 24 channels on one inch centers.

RC DESK-TYPE CONSOLE
Medium gain assembly for computer write-out, telemetering, applications with input signal above 10 millivolts.



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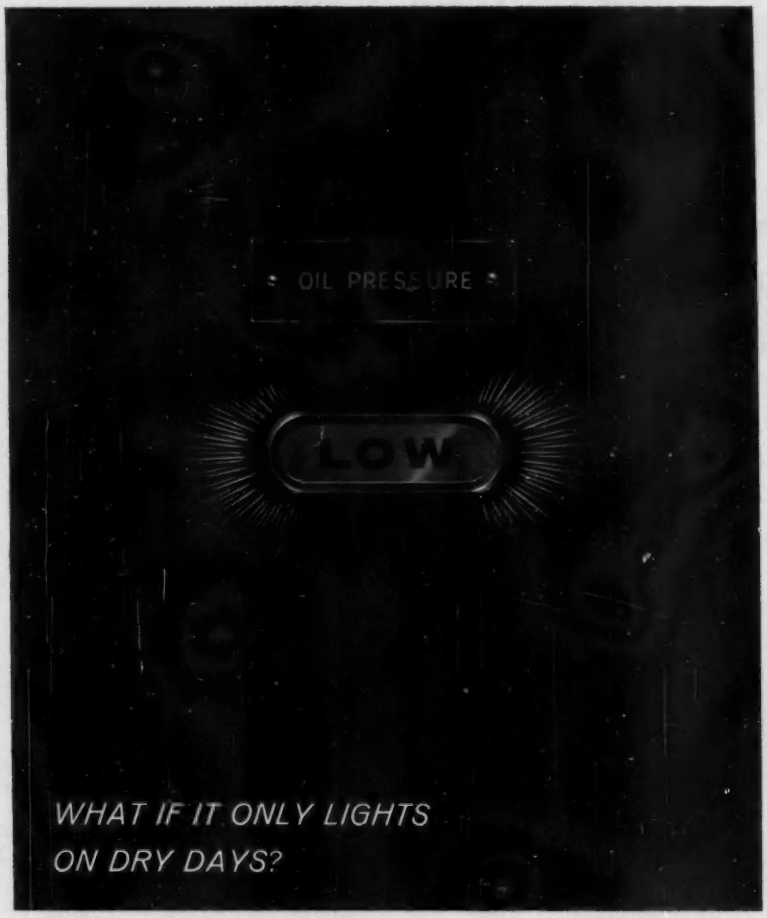

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The *one* way to be sure about a pressure switch is to test it through the whole range of operating requirements . . . not just at 0% humidity or just at room temperature.

Take Model 6547 shown at right which serves in many ways . . . cabin pressure alarm, landing gear position signal, electronic equipment operation, acting parallel to an altimeter. This pressure switch has a calibration accuracy of 20 mm Hg from −65°F to 750°F, 0 to 100% humidity, with an actuation range of 2,000 to 20,000 and 15,000 to 70,000 feet. It weighs only 5½ ounces.

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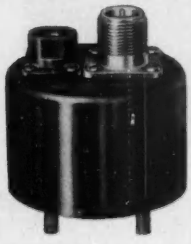
Or you can save yourself six weeks by examining our own test data on a full line of pressure switches for the type that meets your needs best. Call Mr. Charles Colt at Consolidated Controls, Bethel, Conn. Phone Pioneer 3-6721, DDD Code 203.



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FEEDBACK

and long-hand binary/decimal conversions can be accomplished easily and rapidly.

Ed Bukstein
Minneapolis, Minn.

Wants teaching machine.

MR. GORDON PASK—

In the November 1959 issue of CONTROL ENGINEERING (pp. 144-147) you and D. Wiseman presented an article, "Electronic Teaching Machine".

Columbia Records Club is interested in procuring an electronic teacher of the type described in your article provided it is adaptable to IBM alphabetic-numerical key punching machines and/or 10-key adding machines. We need to train many key punch operators for IBM 026 alphabetic key punchers with a high degree of seasonality to the labor demand. Hence, training time and expense is an important factor in recruiting people for this kind of labor.

Will you please advise me if this machine is being marketed in the United States and whether or not it has been engineered for training on IBM key punch equipment or 10-key adders.

Thank you very much for your work in developing this type of equipment and for any assistance that you may provide in applying this type of device to our business problems.

J. R. Farmer, Director EDP
Columbia Records Club, Inc.
New York, N. Y.

Solartron manufactures the electronic teaching machine designed by Mr. Pask. Rheem Mfg. Co, 400 Park Ave., N. Y. 22, represents Solartron in this country for the product. The machine has been programmed for teaching the use of both alphanumerical key punch and 10-key adding machine. Ed.

Wants teaching machine publication.

TO THE EDITOR—

Your article, "The Coming Boom in Teaching Machines" in the June 1960 issue of CONTROL ENGINEERING was of special interest to me. I would like to receive the Automated Teaching Bulletin (p. 24) from Rheem Corporation, but our library has as yet no information on the publication.

J. T. Daniel
Houston, Tex.

Contact The Editor, Automated Teaching Bulletin, Rheem Califone Corp., 1020 N. La Brea Ave., Hollywood 38, Calif. Ed.

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1N457*	1N462	1N626	1N482A	1N484B
1N458*	1N463	1N627	1N482B	1N485
1N459*	1N464	1N628	1N483	1N485A
		1N629	1N483A	1N485B
		1N662†	1N483B	1N486
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1N457	20 mA	.025 μA	5 μA	60V	60V	70V	75 mA
1N458	7 mA	.025 μA	5 μA	125V	125V	150V	55 mA
1N459	3 mA	.025 μA	5 μA	175V	175V	200V	40 mA

*Reverse voltage at which a reverse current of 100 uA flows.
All ratings and characteristics are at 25° C. unless otherwise noted.
Operating temperature range −80° C. to +200° C.

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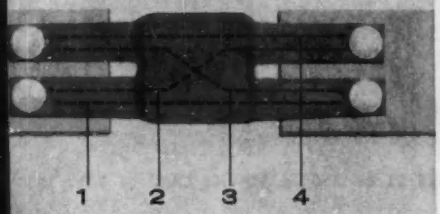
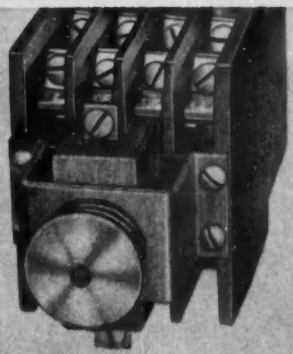
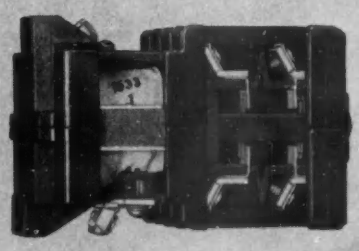
New contact reliability. Parallel bifurcated contacts, which allow four current paths instead of one, provide infinitely greater circuit reliability . . . liberally designed so any current path carries full relay rating.





At last! "Mechanical memory" latch as reliable as the relay itself! No adjustment ever needed. Add latch at any time.

New simplified design! Cutaway view shows basic simplicity. Coil vacuum impregnated to resist damage from humidity, vibration, electrical stress. Terminals can be screw or spade type.



Space savingest relay you've ever seen: New Cutler-Hammer "Compact 300"

Versatile 300 V. control relay is so reliable it's permanently sealed!

Here is the best answer yet to the need for an extremely reliable, small-size 300 V. industrial relay—the new Cutler-Hammer "Compact 300."

Every detail known that affects relay reliability has been improved in the "Compact 300." Bifurcated contacts which make possible *four* current paths rather than one, add millions of operations to the "Compact 300's" electrical reliability.

In fact, we're so confident of its electromechanical reliability, we permanently enclose the "Compact 300." And, if it should be damaged by a fault current, you throw it away and replace it with a new one. Its low price makes this an economical, practical maintenance procedure.

Now think of the space you can save with the "Compact 300." It controls up to eight circuits in panel space only 2″ wide by 2¾″ high. 2, 3, 4, 6 and 8 poles with any combination of N.O. or N.C. contacts are available, of course.

At any time, you can add "mechanical memory" latch with a life equal to the life of the relay. No adjustments are ever necessary. It's another exclusive! Better get full details on the new "Compact 300" now. Send for Pub. ED-L079-S227.

What's new at Cutler-Hammer? New, better products, like the 300 V. relay are coming steadily from our new, expanded plant facilities. We're ready now to help you take care of the great industrial growth of the future. If you are planning ahead and need electrical control assistance, contact the nearest Cutler-Hammer sales office.

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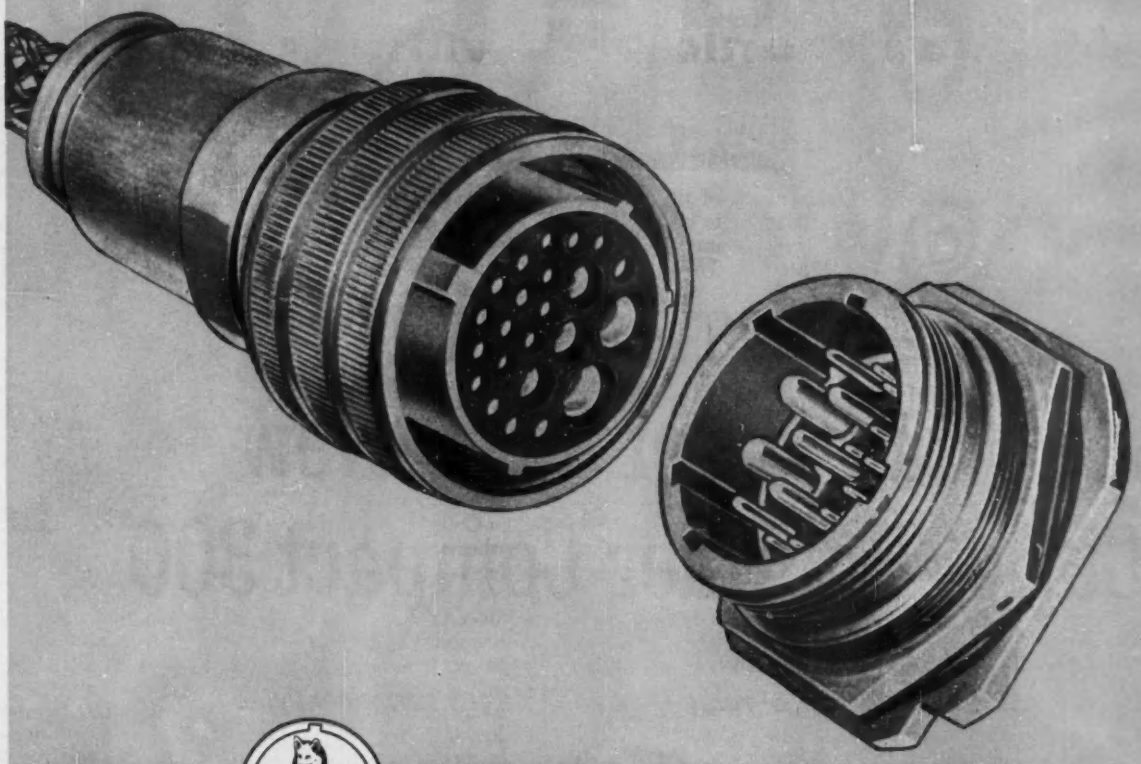

QWLD ELECTRICAL CONNECTORS

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WITH SUCH OUTSTANDING ADVANTAGES AS:

FIVE INTEGRAL KEYS AND KEYWAYS that provide for positive polarization and positive mating—even in blind locations. ***No possible contact damage.*** QWLD connectors can be fully mated and unmated by hand.

HEAVY-DUTY CONSTRUCTION through use of extra-heavy machined or forged aluminum shell components, resilient inserts, silver-plated copper alloy contacts, and rugged cable accessories with new superior gasket design.

TWO NEW SERIES AVAILABLE with the QWLD having standard solder or solderless contacts and the QWLG having provisions for grounding one contact to the shell.

PLUS . . . IMPROVED WATERPROOFING • CLOSED ENTRY SOCKET CONTACTS • SELF-EJECTING COUPLING ACTION • DESIGNED TO MEET MILITARY SPECIFICATIONS • WIDEST RANGE OF CABLE ACCESSORIES.

QWLD is the latest development in Scintilla's long line of multiple conductor cable connectors—and is specially designed to meet the rugged environmental conditions of missile launching equipment, ground radar, or power and control circuits—and heavy-duty industrial applications such as are found in oil fields or mining. Be sure to investigate the new QWLD HUS-KEY* Connectors from Scintilla.

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THE Bendix CORPORATION

Douglas T. Ross
communicates with machines

Designing automatic machines and systems raises one new perplexing problem: how will man tell the new systems what to do? At MIT's Electronic Systems Laboratory, a 30-year old mathematician is worrying out one approach. Douglas T. Ross is designing languages that allow man and machines to communicate with each other.

His first dramatic success was demonstrated last year when the Air Force showed its Automatically Programmed Tool System (APT) for numerically controlled machine tools. APT, says its creator Ross, is a technique for making a manufacturing tool produce what you want from a general or verbal description. With a computer, APT converts symbolic language into a form a machine tool can use.

In APT language any quantity can be described by a symbol. For example, a mechanical part can be described in nonnumerical form, in algebraic form to specify a whole family of parts. Man can then plug in numbers to produce a specific product. When Ross demonstrated APT last year, the system contained 8,000 instructions. Since then his group at MIT has pushed the capabilities of Automatic Programming to 43,000 instructions for the 25 companies of the Aerospace Industries Association in the APT project.

Ross' next project is even more breathtaking. He plans to extend the APT language concept to computer-aided design, so that what APT does for numerical control, his new idea will perform for design. The goal: pour a competent designer's ideas, sketches, and gestures into a computer to assist the creative design process.

To Doug Ross his new project is more than just a way to communicate with machines. It is part of the birth of a new field, one that combines semantics, logic, mathematics, and physics. Ross feels his technique is a whole new approach to solving complex problems. His reasoning: to program a language to instruct an automatic system requires great knowledge of all aspects of the problem and how to go about solving it, allows mechanization of some aspects of "thinking." This new "Queen of the Sciences", says Ross, is only part mathematics and part computer, because there are some aspects that cannot be put into mathematical terms—e.g., the gestures with which a designer conveys an idea to a draftsman.

Such an admission of the weakness of mathematics is not completely expected from Ross, who is a mathematician by training and experience. A 1951 graduate of Oberlin College with a B.A. degree in mathematics, he joined MIT as a teaching assistant in mathematics in 1952.

During his first summer at MIT, he worked in the Servomechanisms Laboratory part-time to earn some spending money, performing computation work on a desk calculator. During the summer a problem in correlation arose and the project had no equipment to solve it. At the suggestion of a friend, Ross turned to Whirlwind, MIT's venerable digital computer. When the summer ended, Ross had finished the computer program but still had to document results, so John Ward, then a project engineer and now assistant director of the Electronic Systems Laboratory, suggested that Ross stay on unless "he really wanted to go back to teach freshman" after his initiation into computer programing and application. Ross has been at what is now the Electronic Systems Laboratory ever since.

Once ensconced in research he continued to work with correlation programs on computers. Next he was assigned to a project to apply a new form of ballistic tables to airborne fire control system evaluation. This work led into establishing sophisticated data reduction techniques, and from this he was propelled into a project to design a data reduction system to evaluate the fire control system on the B-58 Hustler bomber.

During this project Ross became interested in manual intervention in computer operation—a technique that

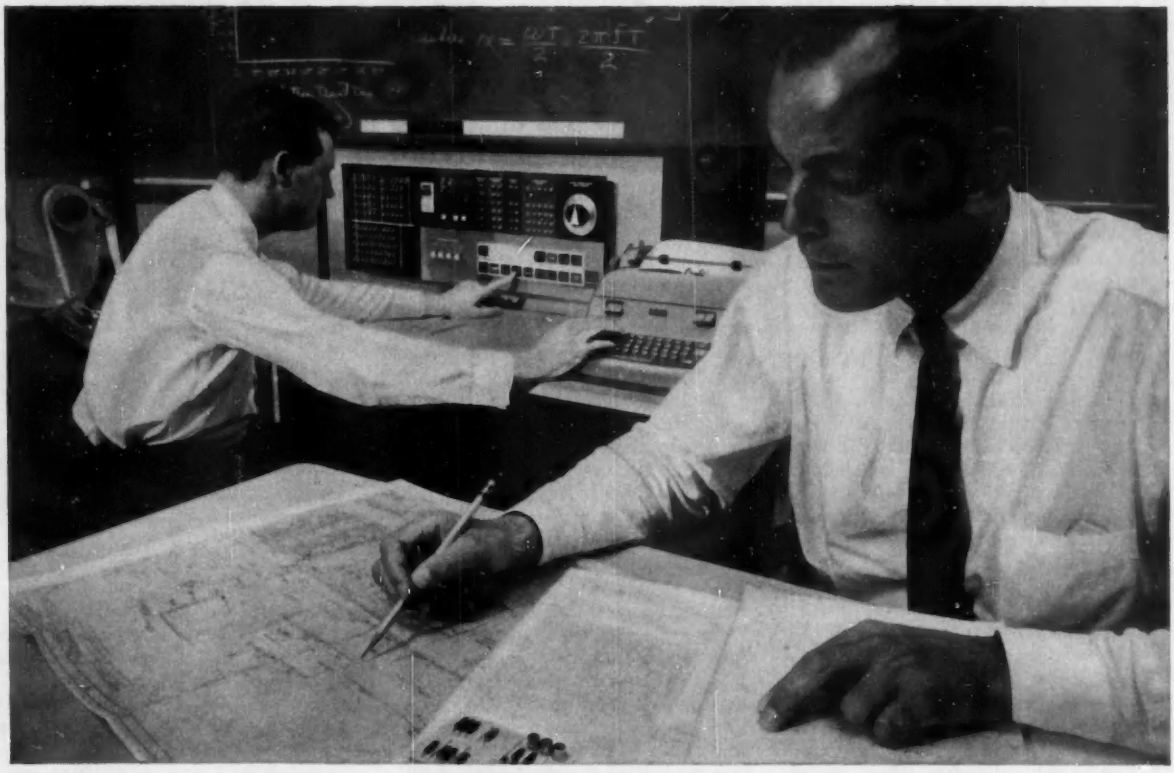
enables man to communicate with the computer on a real time basis. He says the concept is applicable when you don't know enough about a problem to make the program completely automatic. To communicate the man pushes buttons, each pushbutton corresponding to a word or phrase of the language. The machine communicates with the man through oscilloscope displays that can spell out messages or present numerical answers. Manual intervention started Ross' interest in language for automatic systems.

The crewcut Ross is blessed with concentration ability so deep that he can perform mental programming acrobatics even when he is watching television at home with his wife Patricia and their three daughters (and dog). During one group of viewing sessions he constructed a hypothetical universe of matter as a mental exercise, was delighted to discover that his simplified world was relativistic.

Ross expects his Queen of the Sciences will leave its mark on control engineering. In a thoughtful mood he once said, "We are in a period not too dissimilar to that when Newton and Liebnitz invented the calculus. Afterwards, things were never the same." Ross's contribution to man-machine language and its application in the automatic factory is likely to leave the industrial scene so that it will never be the same.

IBM 1620 *data processing system*

...the most powerful engineering computer in its low price class



The new IBM 1620 is a desk-size engineering computer that offers you more computing ability per dollar than any system in its price class.

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Newsbreaks In Control

● TCI Eyes "Most Automatic" Mill

Birmingham—Most automatic steel mill in the U.S. is to be built here by the Tennessee Coal and Iron Co., division of U.S. Steel over the next couple of years. Engineering has been assigned to the Blaw-Knox Co.; control supplier (or suppliers) has not yet been designated.

● A New Approach to the Neuron

Palo Alto—Office of Naval Research is supporting development of the neuristor, a concept proposed by Stanford Research Institute's H. Crane. Psychoneurologists say the neuristor exhibits many of the properties of the neuron, the key cell of the human brain, and construction appears to be feasible. Crane's concept involves moving a pulse down a line, in some ways like a delay line, to a two-pronged branching point. Once the pulse has passed, the line becomes refractive and will not carry another pulse. ONR believes the neuristor may be useful in learning machines.

● M-H Plans New Systems Group

Pottstown, Pa.—A new group to design and build control systems will be set up here by Minneapolis-Honeywell. The new installation will concentrate in one plant the company's systems work which has previously been spread in many divisions: Philadelphia for process control, Beltsville, Md., for data handling, and Denver and Los Angeles for military systems.

● New Trend for Automatic Drafting

Seattle—To solve the problem of preparing full scale section drawings for its proposed 727 jet transport, Boeing Aircraft is preparing drawings directly from computer tapes by inserting a ball point pen in the tool holder of a numerically controlled milling machine. At least three companies—Hughes Aircraft, Universal Drafting Co., and Electronic Associates—are developing automatic lofting and drafting machines to make high precision drawings on areas from 4 x 8 ft to 5 x 12 ft. Prices: from $80,000 to $250,000.

● Automatic Ships for Navy?

Washington—Navy researchers are experimenting with a new concept for surface fighting ships. New capital ships, according to this approach, would be as automatic as the Navy can make them, require small crews. Replacing some crewmen would be a number of computers: for startup and shutdown of the power plant, for navigation, for steering, for fire control, etc.

● Boston Eyes Automatic Transit

Boston—The Metropolitan Transit Authority has started a feasibility study to determine if its lines can be converted to full automatic operation—with "absolutely no personnel on the trains" according to system General Manager Thomas J. McLernon. If the study proves technical feasibility at a cost, Boston will have the first completely automatic railroad in the U.S.

Mobile Field laboratory is equipped with air pollution and standard meteorological measuring devices. It operates automatically, unmanned, seven days a week. Data is picked up daily and studied.

Particulate matter is measured by this dust sampler which passes air samples over a filter built in the form of a continuous paper tape.

Smog Instrumentation: apathy numbs progress

Spectrometers and chromatographs have been enlisted in the battle against smog, and additional new instruments are needed. But apathy is likely to numb the acquisition and development of air pollution instrumentation.

LOS ANGELES—

Air pollution is a serious health problem in a growing number of cities and likely to remain so. Although some new measurement techniques have been enlisted in the battle to detect and analyze the polluting materials, the apathy of practically everybody threatens to stall any widespread program to detect, monitor, or clean up the nation's air. Meanwhile, interest in air pollution instrumentation stays in the curiosity stage.

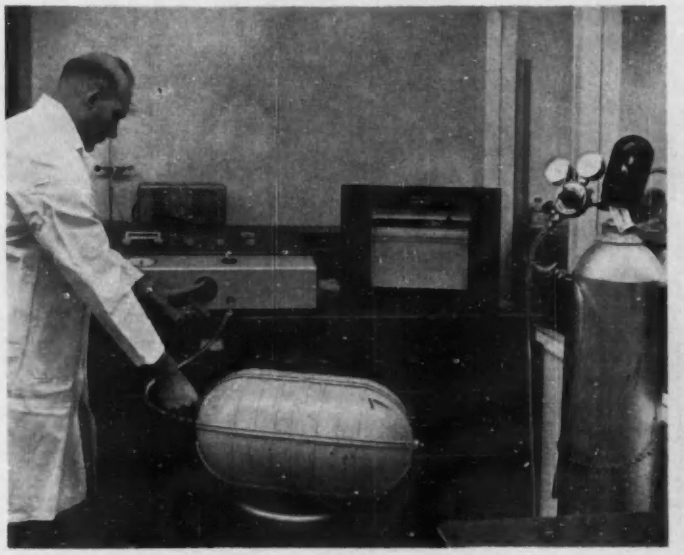
Even in Los Angeles, which has the most publicized smog problem in the world, the budget for research and personnel to work in air pollution has been cut back this year. In the New York metropolitan area, where for many years the industrial suburb from Jersey City to Secaucus, N. J., has been called a "garbage heap" because of the offensive, eye-watering atmosphere, public officials still have shrugged off any program to correct the malodorous air.

Probably half of the total air pollution instrumentation in the United States is located in California. The two biggest users: the Los Angeles County Air Pollution Control District and the Bay Area Air Pollution Control District in San Francisco.

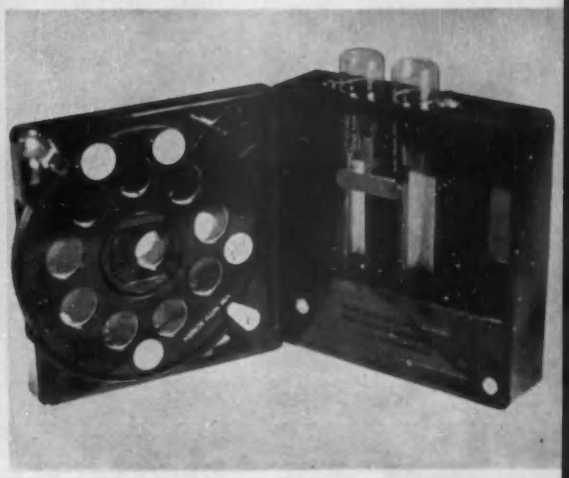
What's happening in the field was summed up last month by a specialist in Los Angeles who told CtE that a steady stream of visitors and mail ply the Air Pollution Control District with questions about measurement techniques and instrumentation. The questions come from the U.S. Public Health Service, industrial firms, cities, and education and research institutions—not only in the U.S., but they also come in from Western Europe and Asia.

These inquiries are preliminary ones, says the LA engineer. Before the questioners can make any progress they first must sell city councils and state legislatures that a need for an air pollution program exists, then they have to sell a lot harder to get the politicos to appropriate the necessary funds for instrumentation and personnel. To date, only a handful of air pollution experts have been able to clear that last hurdle.

• **What to measure**—One reason for the apathy on the part of city and state officials, is that it is hard to pin down the blame for smog and just as hard to nail the deleterious effects. Nobody will accept the blame for air pollution. Medical men agree that



Hydrocarbon content is measured by gas chromatograph. Hydrocarbons are first solidified by a freezeout trap of liquid nitrogen.



Oxidant content is measured in the field by this hand-held Lovibond comparator.

smog probably contributes to cancer, can irritate throat and nasal membranes, and causes eye watering. Rarely have the results been as dramatic as in London, England, where smog contributed to the deaths of over 5,000 people in 1952.

Two types of contaminants appear to be the cause of the trouble: 1) particulate matter such as soot, dust, or metal particles and 2) oxidants, gaseous compounds that undergo photochemical oxidation to produce peroxides that burn eyes, damage vegetation, and reduce visibility.

Cause of the first is thought to be industrial plants with faulty smoke stacks, incinerators, and rubbish dumps. Although many smoke control programs have been started, enforcement has frequently been lax because officials are reluctant to cite the industries on which they are dependent economically. The second type of contaminants seems to be associated with the hydrocarbons emitted by automobile engine exhausts and hydrocarbon gases emitted by petrochemical processing plants. In this case too, the elimination of the oxidants would appear to require stern measures like the recent law passed in California requiring smog suppressors on all automobile exhausts in a few years. California, however, is an exception; most states are not yet willing to press for such restrictive legislation.

• **How much dirt?**—To determine the amount of particulate matter in the air requires physical air sampling. One method is to suck a fixed volume of air past a piece of filter paper which is weighed before and after a 24-hour exposure to the air stream. From the weight a tester can calculate the number of micrograms of matter per cubic meter of air. Instruments to make this measurement cost about $150; typical manufacturers: Staplex, Mine Safety Appliances, and Davis Instrument Co.

Because this technique requires 24 hours to make a measurement, it is being replaced or complemented by a Gemeon air sampler made by Research Appliance Co. (Allison Park, Pa.), a device costing about $350 and producing a reading as frequently as every two hours, the cycle chosen by the Bay Area Air Pollution Control District. Here is how it works. Air passes through a filter that has been built in the form of a continuous tape, the flow hitting only one section of the tape during the sampling period. At the end of the sampling period, the tape is moved automatically so another portion is exposed for the next period. Evaluation depends on the relative darkness of the spots produced as compared to a standard index.

• **Any oxidants present?**—To an individual suffering in a smog, the oxidants cause the most discomfort. The amount of such compounds in the air can be determined either by a manual method or an automatic one.

In the manual method, the air to be tested is bubbled through a small quantity of phenolphthalein at a rate of 1 liter per min for 10 min. Oxidants in the air turn the solution pink, and the degree of pinkness determines the concentration. To measure this concentration, the solution is passed into a colorimeter. A slide rule calculation converts the percent light transmission into percent oxidants in the air sample.

An automatic method, called the Standard Method or the Potassium Iodide (KI) Method, passes air through a small quantity of potassium iodide solution flowing continuously from a reservoir. Oxidants react to form atomic iodine in quantities directly proportional to the amount of oxidant in the air sample The solution, yellowed by the iodine, then flows continuously into a photocell chamber which measures light transmission, converts it to a signal that is recorded graphically.

One advantage of this method, besides its being continuous and automatic, is the stability of the KI solution, compared to phenolphthalein which usually has to be refrigerated. One disadvantage, however, is that some peroxides do not react with the solution, so that a KI method reading

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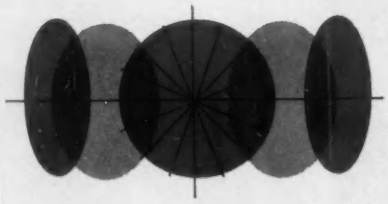

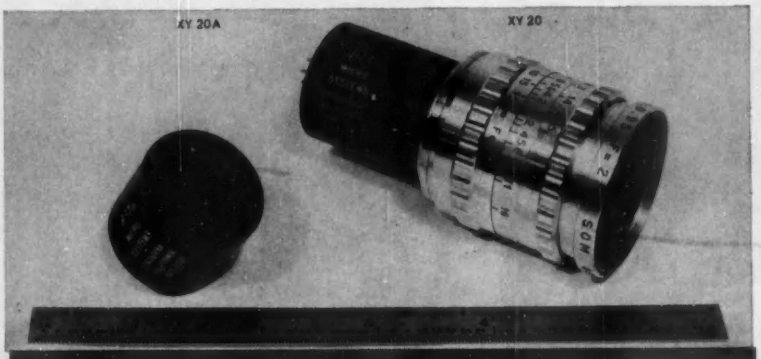

A REVOLUTIONARY SEMICONDUCTOR DEVICE The Radiation Tracking Transducer detects the position of a source of radiation in two axes in microseconds with no moving parts.

FEATURES—Wide field—plus or minus .2 inches • High resolution—less than .000001 inch • Fast response—5 microseconds • Visible to near infrared—.5 to 1.1 microns • Single silicon element • Self-generating • Simple—only four output leads

2 MODELS — IMMEDIATELY AVAILABLE FOR EVALUATION AND APPLICATION DEVELOPMENT

XY-20A *is sealed, anodized aluminum package, with calibration chart and connecting cable.*

XY-20 *as above, with 25°, f:0.95, F=1" lens.*

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WHAT'S NEW

is almost always lower than a phenolphthalein measure.

To measure oxidants the San Francisco BAAPCD, for example, uses both methods. It has purchased a number of Lovibond comparators, an English phenolphthalein device that costs about $40 and can be used in the field as well as in the laboratory. It converts degree of pinkness directly to percent oxidants in the air sample. In the laboratory two photoelectric colorimeters are used; one costing about $3,000 performs correlation work, the other costing $300 does less delicate testing.

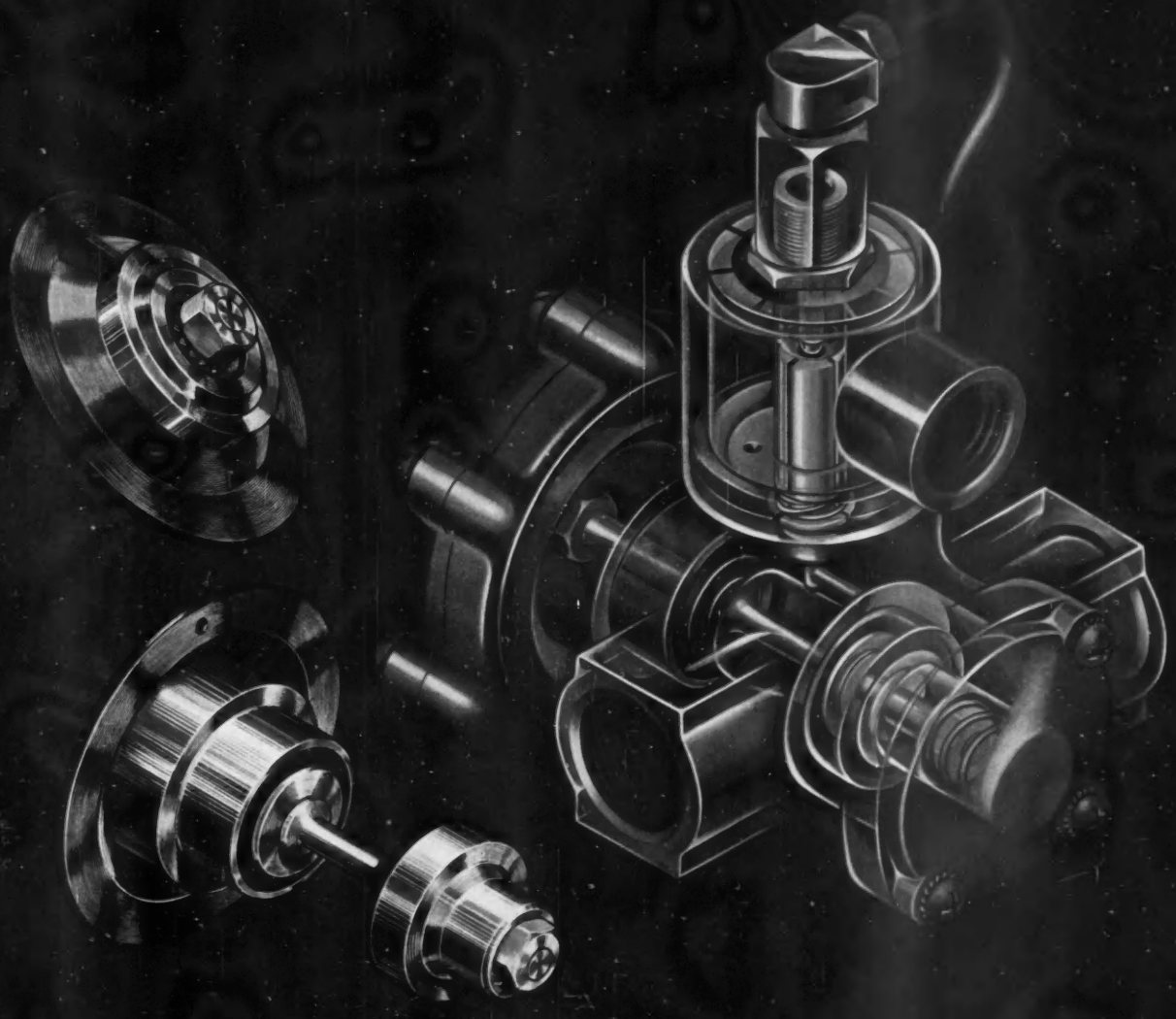
The Bay Area's KI device, a Krueger Oxidant Recorder made by Beckman Instruments (cost: about $6,000), is housed in a truck-borne mobile laboratory which makes periodic readings throughout the district.

• **A trace of hydrocarbons**—Probably the most difficult contaminant to measure is the hydrocarbon content that seems to do a lot of damage even in very small quantities. Much of the effort of the Bay Area group since it was established in 1958 has been aimed at identifying and measuring hydrocarbon components in the air. Some of these compounds are photochemically active and can readily react with other substances, so that air contaminants may be found later in a different form as a result of physical, chemical, or photochemical changes and interactions.

The infrared spectrophotometer has proved to be a big help in measuring these hydrocarbon concentrations. For one thing the instrument can analyze low concentrations—down to a few parts per million—even from small samples whose volumes are only 25 to 50 liters of air. Direct laboratory analysis previously required samples as large as 5,000 liters collected continuously for periods up to 80 hours.

The gas chromatograph also functions as a valuable analytical complement to the spectrophotometer. The Bay Area group, for example, has modified a Beckman Chromatograph to concentrate small quantities of contaminants present in some of the large volume samples that are taken. A freezeout trap of liquid nitrogen concentrates the hydrocarbons by solidifying them before analysis.

• **Other gas detectors**—In Los Angeles, which has one of the most active air pollution groups in the world, additional instruments are refining the analysis of oxidants. For example, LA uses a sulfur dioxide autometer, built by Leeds & Northrup, to measure concentrations of that



SKINNER *2-way and 3-way Solenoid Valves*

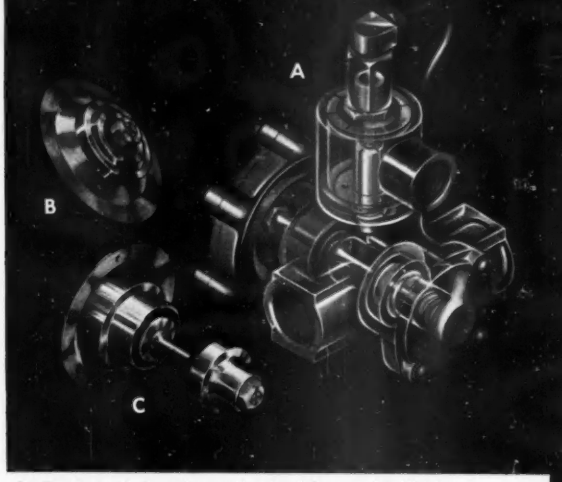
for high flow, heavy-duty industrial use

Skinner combines unique diaphragm assembly and V5 solenoid operator in new L Series valves

Skinner has now combined its famous V5 solenoid operator with a unique diaphragm assembly in a new line of two-way and three-way valves—the versatile L Series.

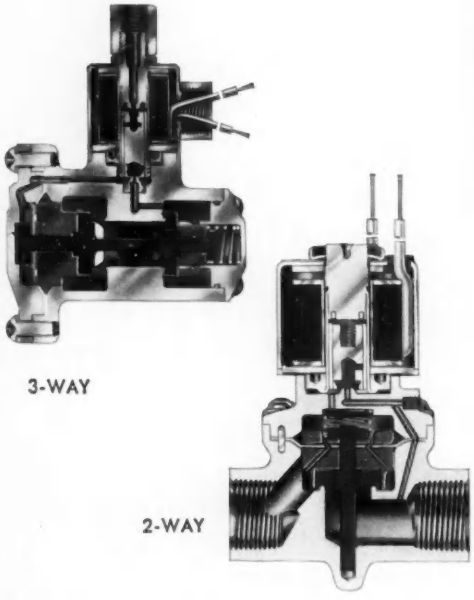
Unusually long life is assured by this new diaphragm assembly. The 3-way diaphragm consists of two tough laminates of nylon fabric coated with a Buna-N rubber separated by a thin Teflon disk. The assembly is virtually 100% supported in the open and closed positions with only a very small area exposed to pressure differential during operation. Life tests show that this type of diaphragm far out-performs all others tested.

The two-way diaphragm and spindle assembly supports a seal retainer and soft, synthetic seal which provides bubbletight sealing of the main orifice. This seal fits on a shoulder which extends beyond the seat and helps to cushion the closing motion—thus minimizing water-hammer.



A—Transparent view of normally closed 3-way solenoid valve
B—Front view of diaphragm assembly
C—Spindle seal retainer and diaphragm assembly

Low cost 2-way and 3-way valves to meet your high flow industrial requirements



Cutaway views of 2-way and 3-way valves showing how the unique diaphragm assembly and solenoid operator are combined in these new valves.

Skinner L Series solenoid valves feature forged naval brass bodies, stainless steel and brass internal parts. They are available normally closed, normally open and directional control in standard and explosion-proof construction.

In addition to the many exclusive features, these Skinner valves are low in price, and with one model—a 2-way normally closed valve—available at especially low budget cost.

All 3-way and 2-way normally open valves are supplied with a piped exhaust return. For catalogs and complete information, contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

SKINNER L SERIES SPECIFICATIONS

	TWO-WAY	THREE-WAY
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Orifice Sizes	½", ¾", 1"	⅜", ½", ¾"
Operating Pressure Differential (Minimum)	5 PSI	5 PSI (⅜" 10 PSI)
Operating Pressure Differential (Maximum)	150 PSI	150 PSI
Position	Normally closed, Normally open	Normally closed, Normally open, Directional control
Leakage	Bubbletight	Bubbletight
Temperature Range (Ambient and Media)	Minus 40°F to plus 180°F	Minus 40°F to plus 180°F

*has ½" orifice

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WHAT'S NEW

gas, which are usually low in Southern California. The device relies on the effect of conductivity change when sulphur dioxide contacts an aqueous reagent containing hydrogen peroxide.

A carbon monoxide analyzer, an infrared device built by Mine Safety Appliances, is used in the field. An ozone photometer, built by Harold Kruger Instruments Co., compares the intensity of light of 2,537 Angstroms (a wavelength ozone absorbs readily) transmitted through two cells in parallel; one holds a sample of untreated air, the other contains a sample from which the ozone has been removed. And a nitrogen oxides recorder measures the concentration of both nitrogen dioxide and nitrogen oxide.

• **New instruments needed**—Instrumentation for air pollution is far from reaching the mature stage. Experimenters in the field would like to see some new instruments developed, particularly for detecting hydrocarbons. One such desired device is an automatic monitoring device that would detect reactive unsaturated hydrocarbons on a continuous basis. Other specialists would like to see a field instrument capable of measuring low concentrations of hydrocarbons right at the point of emission. Present sample taking, even with the spectrophotometer, is still cumbersome.

An urgent need exists today for an objective opacity measurement device that could measure the opacity of a smoke plume regardless of the color of the plume or the weather.

Another area is correlating smog intensity with visibility. One approach is to use a light-scattering photometer, like the $1,700 instrument and recorder built by Engineering Specialties Co. But the Bay Area group is currently trying to build a device of its own based on this theory: measure the degree of blackness of the target and compare it to the brightness of the horizon in an instrument calibrated to the degree of visibility.

All these new instruments must have one characteristic in common: a low price tag. The difficulty of getting anti-air-pollution budgets dictates it. For example, even in enlightened Los Angeles, the annual budget for instrumentation, research and personnel in air pollution is only $3,402,459. In San Francisco the entire budget is $564,000. Neither budget offers much money to combat the gigantic smog problem facing most industrial cities.

—Donald Winston
—Michael Murphy
McGraw-Hill News

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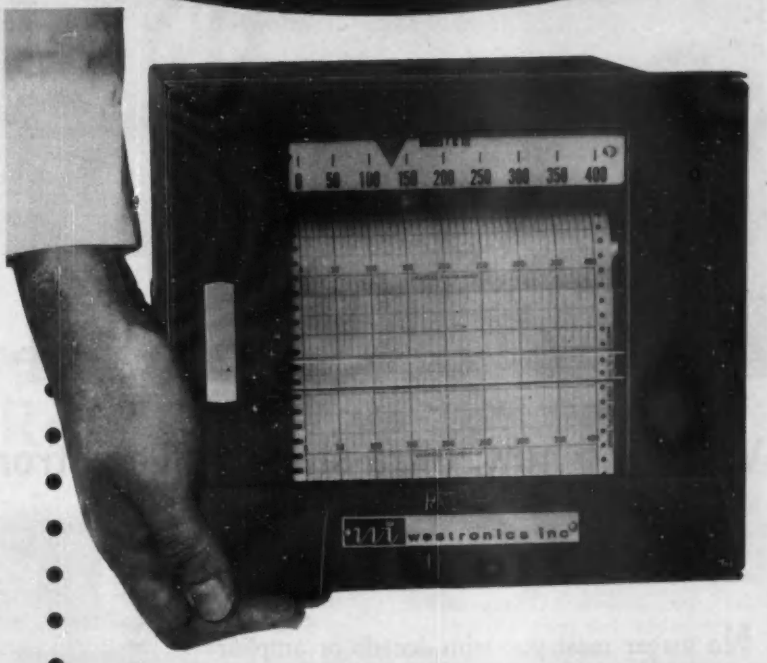

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BRIEF SPECIFICATIONS: Accuracy ±0.01% . . . speed 3 milliseconds per reading . . . input impedance 10 megohms . . . "anti-jitter" circuit . . . DC voltage ranges ±9.999/99.99/999.9 . . . millivolt ranges with preamplifier ±99.99/999.9 . . . AC ranges with AC/DC converter 9.999/99.99/999.9 from 30 cps to 10 kc . . . 98% plug-in modular construction . . . digital output in both decimal and binary coded decimal form . . . simple plug-in accessories for automatic data logging and measuring systems . . . complete, $6,150.

Originator of the Digital Voltmeter

non-linear systems, inc.

DEL MAR (SAN DIEGO), CALIFORNIA

Here are the highlights of the 1961 military budget as they apply to the measurement and control industry.

HIGHLIGHTS FROM 1961 DEFENSE BUDGET
(in millions of dollars)

	New Contracts		Expenditures	
	FY 1960	FY 1961	FY 1960	FY 1961
PROCUREMENT				
Aircraft	$5,900	$6,000	$6,700	$6,000
Missiles	3,500	3,800	3,500	3,500
Shipbuilding	1,500	1,700	1,600	1,600
Ordnance & vehicles	818	1,000	600	691
Electronics and communications	1,300	1,200	898	1,000
Other	476	539	623	694
TOTAL	$13,994	$14,239	$13,921	$13,485
RESEARCH, DEVELOPMENT, TEST AND EVALUATION				
Basic sciences	$ 549	$ 535	$ 429	$ 509
Aircraft	502	446	462	451
Missiles	1,500	1,500	1,300	1,500
Ships	164	151	139	138
Astronautics	408	318	355	305
Ordnance & vehicles	199	177	197	192
Other	558	460	509	480
TOTAL	$3,880	$3,587	$3,391	$3,573

FY = Fiscal Year

Control's Share of Military Budget Continues to Rise

WASHINGTON—The military budget for fiscal 1961 is the biggest the U. S. has ever had in peacetime. But increases in the $41 billion spending plan are the result of rising costs rather than additional purchases or projects. A close perusal uncovers some changes in traditional spending habits to such newly active areas as underwater instrumentation and control, and the control industry seems to be benefiting from such switches. The control industry's share of the budget appears to continue to rise.

You get some idea of the potential from these figures:

▶ Military experts estimate that 35 percent of all funds spent on the development and production of guided missiles goes for electronic controls, measurement systems, and related equipment. Control's share, however, appears to be stabilizing.

▶ The percentage of aircraft money spent on electronic controls continues to rise sharply with the added emphasis on automated flight, navigation, and fire controls for manned aircraft. On the average, measurement and control represents 30 percent of the cost of an airplane. For some aircraft—the Convair F-106 all-weather interceptor, for example—over 50 percent of the airplane's costs is electronic gear.

▶ Electronic measurement and control systems are key elements in two other growing military programs: antisubmarine warfare and space technology. The ASW program will total $1.7 billion this year, up half a billion dollars in contracting over fiscal 1960. A breakdown of how the money will be spent:

Aircraft procurement ..... $340.1 million
Ship construction ..... 762.3 million
Ordnance and ammunition.. 56 million
Electronics procurement.... 25.5 million
Research, development, test, and evaluation..... 180.5 million

Electronic procurement will run this way: sonar and detection equipment, $22 million; communications, $2.6 million; trainers, $862,000.

ASW research, development, test, and evaluation expenses are estimated this way: classification, detection, and localization equipment—$63.4 million; weapons, ordnance, and fire control—$64.2 million; vehicles and propulsion equipment—$29.6 million; and "collateral, supporting, and related equipment"—$23.3 million.

• **The major programs**—Here is what is happening in the major programs in which measurement and electronic control systems play a key role:

• **In aircraft**—The slight rise in new aircraft orders reflects plans of the three services to hike production of several types of planes—despite the talk that manned aircraft are becoming obsolescent in modern warfare.

The Air Force is boosting production of the Republic F-105 fighter-bomber by 50 percent this year, buying jet transports, and is continuing output of the Boeing B-52 and KC-135 and the Convair B-58. Army procurement of light aircraft will be increased 35 percent. Navy orders will be stepped up almost $300 million for the North American Aviation A3J, McDonnell F4H, Chance Vought F8U-2N, and antisubmarine and

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Consolidated takes you all the way in finding and measuring vibration . . . with an airborne system for turbojet and turboprop engines . . . and meters and filters for analysis of turbine engines in test cells and on run-up stands . . . with ground equipment that detects and measures vibration in such static industrial devices as pipelines and air-conditioning systems.

Engineer checks out airborne vibration amplifier at Consolidated Systems Corp.

Where's your vibration problem?

If it's airborne, **consider Consolidated Systems Corp.'s vibration-monitoring system. Its transistorized design and printed circuitry assure reliability and compact packaging. The four-channel modular amplifier is easily accessible and the four CEC vibration transducers are operative to 500°F. This system requires only 5 watts.**

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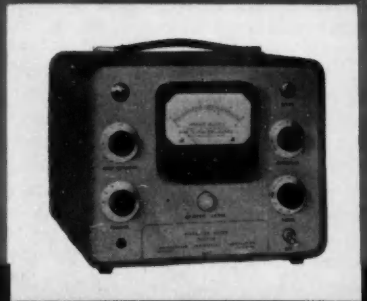

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CEC's portable Type 1-117 Vibration Meter is equally efficient in the field, in the laboratory and on the production line. Provides direct indications of average vibratory velocity and peak-to-peak displacement on a large, easy-to-read meter.

Write for Bulletin CEC 1638C-X3.

Transducer Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

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WHAT'S NEW

tanker-assault planes. On the other hand the Air Force has curtailed new procurement of interceptor planes.

On the R&D side, the Air Force killed or slashed two big projects in the past year. North American Aviation's F-108 long range fighter-interceptor was cancelled, a program in which International Telephone & Telegraph Corp. held contracts for major control subsystems. North American's project to develop the Mach 3 B-70 bomber was drastically cut back to build only two prototype planes for flight experiments. Virtually all work on control systems was curtailed. Among the major subcontracts cancelled: IBM, bombing and navigation subsystem; Sperry, auxiliary gyro platform; Westinghouse, defensive subsystem; Motorola, mission and traffic control; NAA-Autonetics, automatic flight control; and John Oster, power plant instrumentation.

Now it is likely the B-70 project will be resumed on a larger scale. Congress added $190 million extra to the administration's $75 million budget for the project to reinstate it as a complete weapon system. This would mean reinstatement of key R&D subcontracts.

Other aircraft R&D money is going into Army mobility and reconnaissance planes; Navy long-range search, antisubmarine, and fleet air defense aircraft; and Air Force short and vertical takeoff planes, the Dyna-Soar boost-glider, orbital vehicles, aircraft nuclear propulsion systems, and a new heavy transport aircraft.

• **In missiles**—The Defense Dept's Advanced Research Projects Agency is hiking its missile range measurements program to $57 million this year—$11 million more than last year. Purpose is to study physical phenomena associated with missile launching, flight, and reentry, etc.—to aid development of detection, discrimination, tracking, and intercept techniques. Work will be divided among visual, radiation, infrared, and ionization projects.

The bulk of this year's instrumentation increase will go into a radar installation at Kwajalein Island and other apparatus for the Pacific Missile Range running southwest of the Vandenberg AFB-Pt. Mugu complex.

On weapon systems, quantity production is now underway for a wide range of missiles: the Navy's Sidewinder and Sparrow air-to-air rockets, Polaris ballistic missile, Bullpup air-to-surface, and Tartar, Talos, and Terrier antiaircraft missiles; the Air Force's Atlas and Titan ICBMs, Hound Dog

←CIRCLE 38 ON READER SERVICE CARD

air-to-surface missile, Quail Decoy penetration missile, and Bomarc interceptor; and the Army's Sergeant, Hawk, Lacrosse, Redeye, Nike Hercules, and Little John Missiles.

In research and development, projects being pushed the heaviest are Navy's Eagle air-to-air missile, the Air Force's Minuteman ICBM and Skybolt air-launched ballistic missile, and the Army's Nike Zeus antiballistic missile system. Bendix is Eagle's prime contractor; Autonetics is contractor for Minuteman guidance; Douglas Aircraft is Skybolt's prime; and Western Electric is Nike Zeus prime contractor with Sperry Gyroscope, RCA, and Remington Rand Univac as major subcontractors.

The Army's effort to begin production and deployment of Zeus is still stymied. Defense Dept. R&D officials believe that while the system would be effective against low-rate-of-arrival single warheads, Zeus's firepower could be easily saturated by oncoming enemy missile warheads and decoys. So the production decision on Zeus has been held back until the system's capabilities can be expanded.

• **Space technology**—The two major military projects are the Air Force's Midas infrared warning and Samos reconnaissance satellites. Lockheed Aircraft is prime contractor for both. Midas contracting plans have been jacked up from $52 million last vear to $100 million, Samos from $160 million to $200 million.

Smaller astronautic R&D budgets are set aside for the Navy's Transit navigation satellite and the Army's Courier communications satellite.

• **Antisubmarine warfare** — R&D emphasis is being placed on detection and classification devices and techniques. Scientists are striving to produce the long range, positive identification device needed to spot the nuclear powered sub.

The Navy's arsenal of antisub weapons stacks up impressively. There are new lightweight homing torpedoes —submersible guided missiles—to track down and destroy enemy submarines at long ranges. These can be launched from ships, aircraft, or subs.

Destroyers and frigates are now armed with a rocket-propelled depth charge which can be fired quickly in any direction from a trainable mount. A new rocket-launched torpedo system has been developed which delivers a homing torpedo to a point several thousand yards from the launching ship in seconds, is installed on a trainable mount, and is integrated with the ship's fire control system to obtain a high degree of accuracy.

—Morton Reichek
McGraw-Hill News

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VIBRATION

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CEC'S NEW TYPE 4-123A
VIBRATION TRANSDUCER

Now widely used by the aircraft and electronics industries, detects vibration instantly in operating jet engines while airborne or during ground tests. This rugged, omnidirectional transducer assures a frequency response of 45 to 2000 cps with constant damping over a temperature range of −65°F. to +500°F. *Write for Bulletin CEC 1629-X3.*

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Transducer Division CEC

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All levity aside, there's no need to settle for second-best. With "SCOTCH" BRAND Tapes 158 and 159 you get sharp resolution in high frequencies, good low frequency response—plus the consistent performance of a uniform tape.

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You can pack more pulses per inch, and get either standard or extra playing time with "SCOTCH" BRAND High Resolution Tapes. Your dropout count is lower because uniformity is higher. Only "SCOTCH" BRAND can draw on 3M's more than 50 years of experience in precision coating techniques. The result is a consistent tape with a uniform coating you can depend on for reliable performance.

"SCOTCH" BRAND High Resolution Tapes meet your need for top high-frequency response even in pulse code modulation (PCM) and pre-detection (video) applications; so switch now from tapes that may well be made obsolete by new instruments.

Whatever your application—data acquisition, reduction, or control programming—experienced "SCOTCH" BRAND technology has a dependable tape for the job. Sandwich Tapes 188 and 189 cut headwear, eliminate oxide rub-off, last 10 times longer than ordinary tapes. New Heavy Duty Tapes 198 and 199 give long wear, minimize static charge build-up. High Output Tape 128 gives top output in low frequencies, even at temperature extremes. And "SCOTCH" BRAND Standard Tapes 108 and 109 remain the standard for instrumentation.

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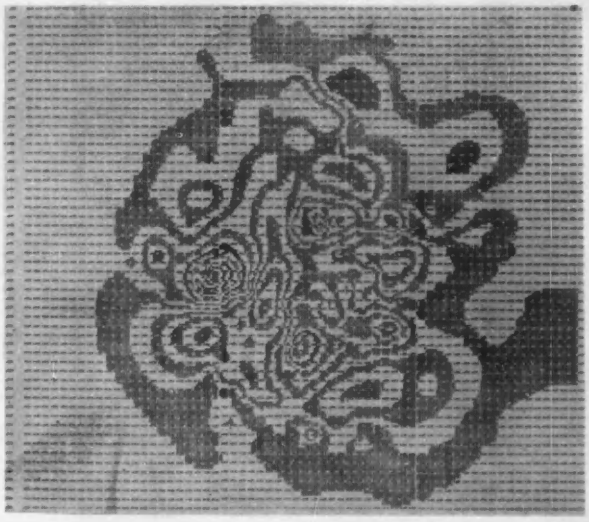
This CDC 1604 computer will receive weather information from 5,000 stations, sort it, arrange it, and compute data for weather maps of the type shown below. Huge volume of data is handled by four Ampex handlers which allow a transfer rate of 30,000 characters per sec.



Typical weather map produced in experiments by the NANWEP group (closeup above). This one was made on an IBM 717 printer. When installation is operational, an automatic Electronic Associates plotter will prepare the maps.

Computer Talks about Weather, Makes Best Predictions

MONTEREY, CALIF.—One evening early in 1961 a Naval officer in the Navy Numerical Weather Problems Group (NANWEP) will take a reel of magnetic tape computer output, attach it to an automatic curve plotter, and turn a switch. Minutes later the plotter will supply him—and the U. S. Navy—with a sheaf of diagrams which will constitute the freshest, most complete, and most accurate ready-to-read weather map ever made of the northern hemisphere.

But that's not all. The first map, though unique, will be only a by-product. The plotters will also spew out, from the same reel of tape, a similar graphical representation showing what the weather pattern will be up to 72 hours in the future. This document—the first of its kind in the history of meteorology—will be sent daily by facsimile transmission to Navy bases throughout the northern hemisphere and to the U. S. Weather Bureau in Washington. It will enable weathermen to make highly accurate predictions for their local areas. It will aid navigators in predicting such phenomena as wave height. And it will be used extensively in weather research.

The next step, after production of weather maps has been made routine, is direct prediction of weather, by computer, for designated local areas with 100 percent reliability. The ultimate goal: control of the weather.

• **Numerical approach**—The numerical approach to weather forecasting is not new in theory. As far back as the 1920's meteoroligists laid the groundwork for a system of weather predic-

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WHAT'S NEW

tion which would involve making the largest possible number of observations over an area, then arithmetically interpolating for those pockets in which observations had not been made.

The resultant weather map, describing the weather as observed at a given time, could theoretically be projected several days into the future by applying six rather primitive equations. These nonlinear partial differential equations describe how the atmosphere, as a fluid, behaves. They break down into three equations of motion, one of continuity, the first law of thermodynamics, and the ideal gas law.

How to solve these six equations by desk calculation proved to be the stumbling block. Instead, meteorologists have had to content themselves with drawing and examining their empirical weather maps and predicting, from experience and knowledge of local weather patterns, what the weather will be in given areas. This "seat-of-the-pants" method provides about 85 percent accuracy, a figure that has not changed appreciably.

With a high speed digital computer, meteorologists now have a way to do all the tedium involved in a strict numerical approach in a short time.

• **Sea of data**—Data input will be handled by a highly complex program now being written for an Avco-Crosley digitizer. The instrument, whose January delivery date is expected to coincide with completion of the programming phase, will convert weather information from punched teletype tape to magnetic tape for introduction into CDC 1604 computer.

To get a comprehensive picture of what is going on meteorologically around the world, NANWEP will receive daily teletype reports from 5,000 weather stations. Most of these stations are western world observation posts, which report in standardized form, but more than 1,000 are weather balloons, whose reports are often erratic. Data will also be taken from Soviet and Red Chinese weather transmissions, monitored and translated before entering the NANWEP system.

• **Only a computer**—The computer will receive this information in whatever order it arrives, and will store signals denoting temperature, barometric pressure, sea water temperature, wind direction and velocity, visibility, cloud cover, dew point, and precipitation in that part of the memory representing the geographical location.

In addition, the computer will analyze its input, converting all tempera-

BLH BUILDS WORLD'S LARGEST LOAD CELL TO ACCURATELY MEASURE 1,500,000-LB. ROCKET THRUST

America's first rocket engine with a launching thrust of 1.5 million pounds is now being developed by Rocketdyne, a division of North American Aviation, Inc.

One of the most critical factors in the successful firing of a rocket or missile is the exact determination of weight and thrust. Present operational rocket engines are tested for weight and thrust by using a series of load cells of no more than 100,000 pounds capacity each, along with allied instrumentation for computing data from the several sources.

Now the BLH development of a single functional cell with a 1.5 million lb. capacity will permit evaluation of total weight and thrust from one source, reducing the number of possible sources of error. Calibration and testing by the National Bureau of Standards has proved the load cell and its instrument system to be accurate to ±0.10% of reading over the full scale from one-tenth to full capacity. The complete system will become part of Rocketdyne's high-thrust test area at Edwards Air Force Base, Calif.

BLH experience and capabilities in force and strain measurement are available for your use, whether in pioneering efforts such as this one, or in the improvement of existing measurement applications. Write for additional proof of BLH capabilities . . . or contact your nearby BLH sales engineering representative for application engineering service.

◀ World's largest single column load cell weighs 2200 pounds, is 44 in. high, 20 in. in diameter.

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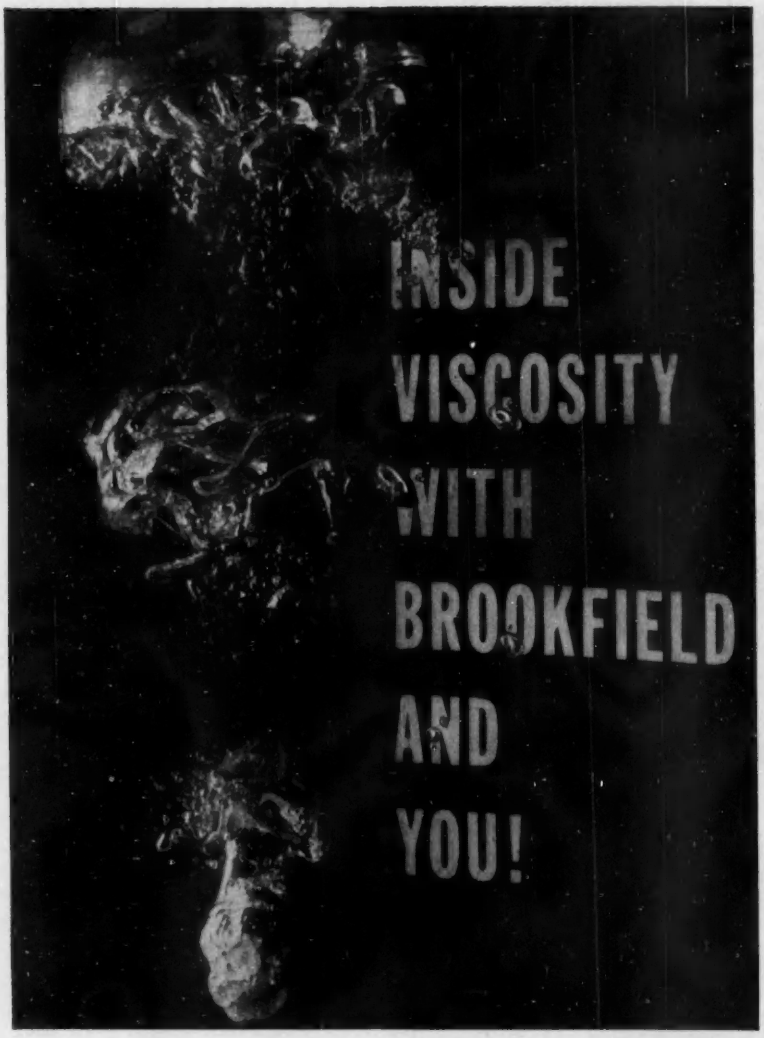

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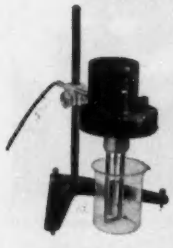

THE WORLD'S STANDARD FOR VISCOSITY MEASUREMENT AND CONTROL

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STOUGHTON MASSACHUSETTS

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WHAT'S NEW

tures to Centigrade and other measurements to the metric system where necessary. And the machine will reject any implausible readings, basing the decision on arbitrary limits set by the programmers and on comparison with previous entries. When all reports are in the computer memory, arithmetic interpolation will automatically supply readings for those points not represented by a reporting station.

At this point the console operator can ask for a tape readout of weather maps based on input and interpolation alone. What comes out is a weather map of the past 24 hours. However, by ordering the computer to solve the equations relating to atmospheric behavior, using the stored input figures as known factors, the computer will supply within minutes a weather map for an immediate future period.

The automatic curve plotter, being built by Electronic Associates, will draw isobars and isotherms on tape command and will print out appropriate numbers for each weather map.

The machine-made maps will provide so much information that several maps will be required to provide all of it in readable form, for example: wind speed and direction and barometric pressure, isotherms, wide scale precipitation, vertical velocity of atmospheric layers.

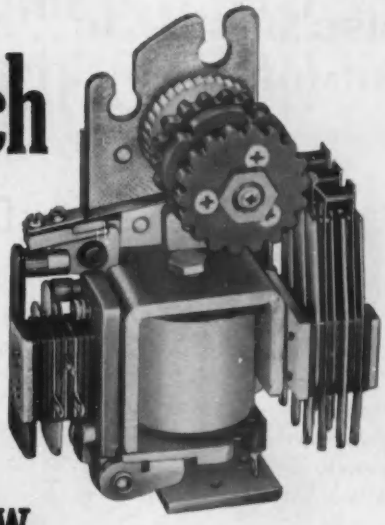
The curve plotter will not be delivered until January; for experimental purposes in the meantime NANWEP is using an IBM 717 printer, programmed to provide a curve effect by shading with numerals.

As NANWEP's program nears operation, a few final problems still have the weather scientists worried. A major difficulty may develop if Russia and Red China switch from radio to closed-circuit teletype transmission of weather data—U. S. is now eavesdropping on communist weather broadcasts. If this source is shut down, NANWEP will be deprived of a vital block of its weather information. NANWEP officials hope that an agreement will be worked out to exchange such information openly.

Another difficulty is a shortage of weather reporting stations. Hurricanes, for instance, breed in a part of the Atlantic seldom traveled by ships; consequently a hurricane can be days old before it is even reported, much less tracked. Possible solutions include setting weather buoys in the ocean and launching instrumented rockets and satellites to fill in missing bits of weather information.

—Donald S. Winston
McGraw-Hill News

Here's a Memory Switch You Won't Forget...



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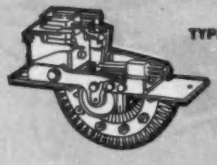

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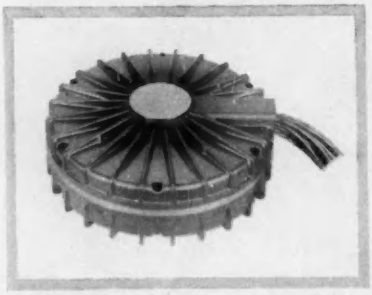

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Optical Programmer for Numerically Controlled Drill Press

LOS ANGELES—In the manufacture of circuit boards, numerically-controlled drill presses have won approval for the time-consuming operation of drilling the large number of holes for connections. But some users have been concerned about the amount of time required to make the punched tapes to program such control. Last month a new numerical control for a drill press promised to make the programming job easier with a new optical programming technique that increases hole positioning accuracy while substantially reducing total programming time. A development of Micro-Path, Inc., the new contour drilling machine, called the MPI 440, has four drill heads, a top drilling speed of 500 holes per minute.

To program the MPI 440, an operator views an etched master circuit board or a negative film of the master on a conventional comparator projector, moves the hole with a positioning control (see block diagram) under a tolerance circle superimposed on the viewing screen, then enters a "drill down" command on the recording tape. Average positioning time is about two seconds.

Currently two methods have been used to program the drilling of circuit boards. In one a steel drill guide is prepared manually, but because of the manual efforts, the placement of holes is not always accurate. In the other method a contact negative, or a first etched board, is read with a toolmakers microscope to determine the X and Y coordinates of each hole. These coordinate values are then punched into a tape to program the numerically controlled machine.

The new system does away with the manual determination of the X and Y axis, which turns out to be the most likely operation for errors to develop. Instead, an operator puts an etched master board (or the negative to be used for contact printing) into a view-

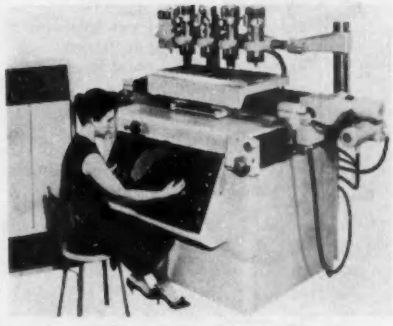
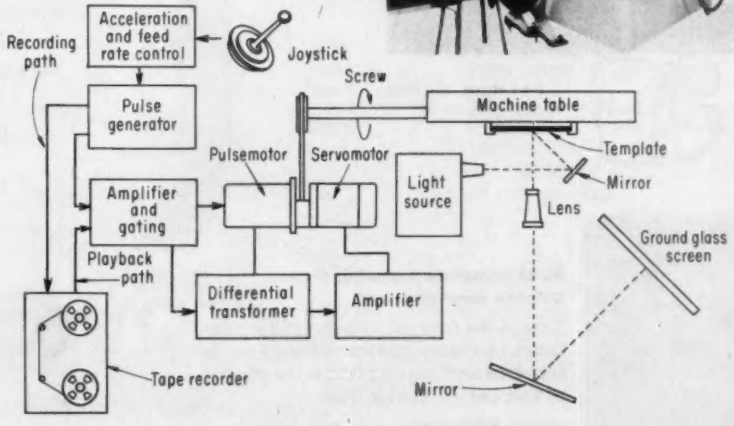


FIG. 1. Optical programmer for new numerically controlled drill press. Joy stick in operator's right hand moves projection of hole on circuit board master within tolerance circle on screen. Operator then enters "drill down" command on recording tape.

FIG. 2. Block diagram of positioning control. Joy stick velocity control has an exponential response.



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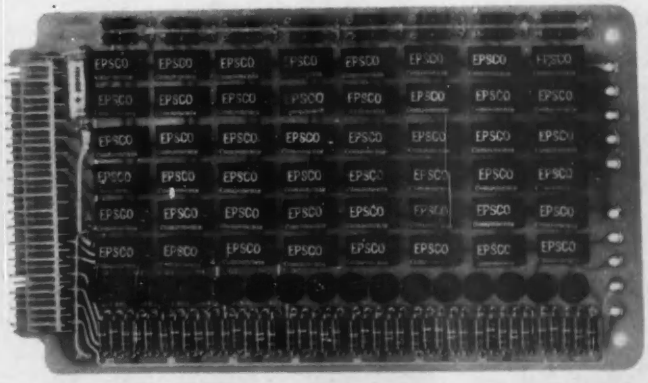

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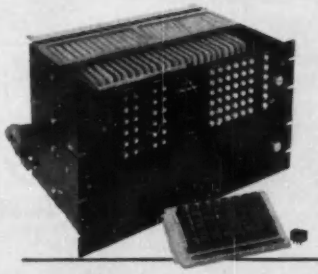

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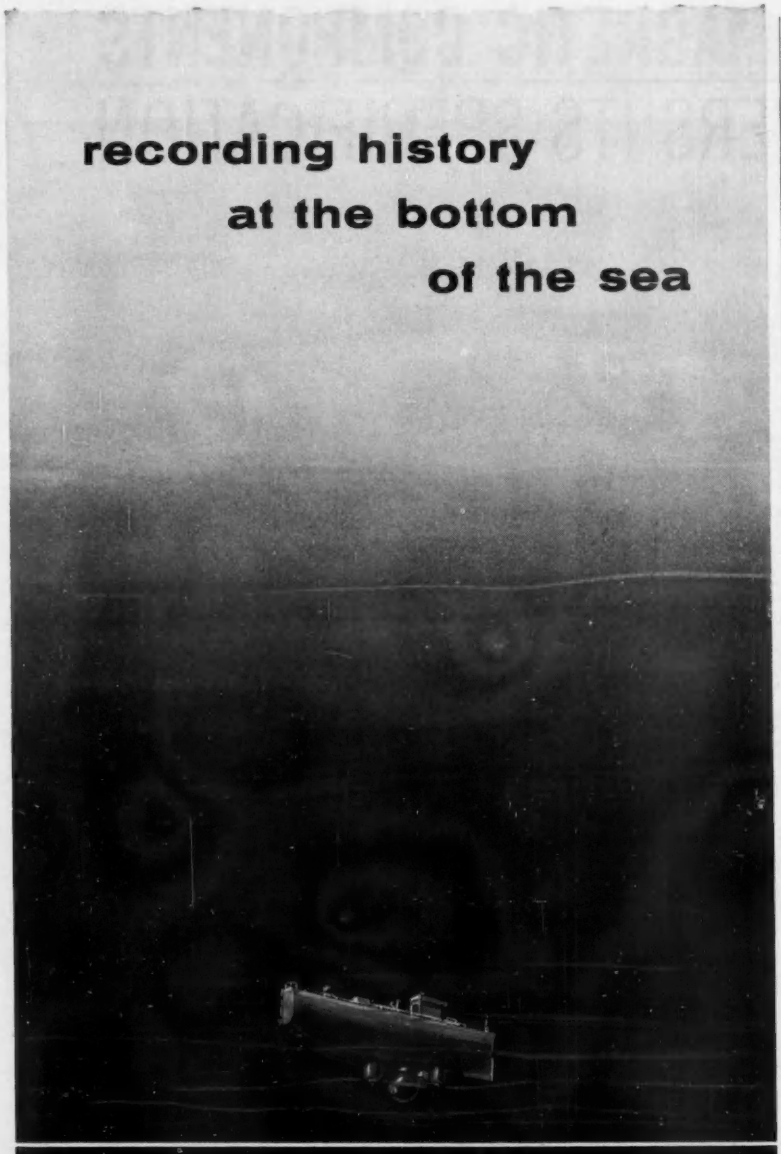
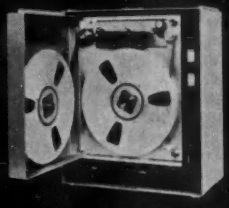


Far below the surface, in a sealed steel ball on the *Trieste* bathyscaph, a new chapter in undersea history is being recorded—on magnetic tape. Operating in an environment of 99% relative humidity, a high-performance instrumentation tape recorder captures a permanent record of depth, temperature, ambient noise, and voice.

The recorder, Precision Model PS-207 as shown at right, was modified for the application by Lockheed Aircraft Corporation, Sunnyvale, Calif., and supplied by them to the Naval Electronics Laboratory, San Diego, for the *Trieste* installation.



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WHAT'S NEW

ing slide under the positioning table, and a small portion of the view is projected. He proceeds from hole to hole following a colored path marked on the board.

To move the positioning table so that a hole fits into the tolerance circle of the screen, the operator moves a joy stick which is a velocity control with an exponential response. As a result, large movements of the control stick near the vertical produce slow movements on the drill table; when the control stick is fully extended, however, the table can move at a maximum speed of 100 in. per min.

An operator can check the accuracy of a program by running the tape. During the replay, he watches the comparator screen to verify that all programmed holes fall within the tolerance circle on the viewer. The machine can play back four times as fast as its programming rate.

In the machines which Micro-Path has built for the A. C. Spark Plug Div. of General Motors, first buyers of the new control, each of the four drill heads can cut 30 holes per minute—with a stack of four boards under each, almost 500 holes per minute. Accuracy of positioning is plus or minus 0.001 in. Price of the complete machine tool is less than $30,000.

—Michael Murphy
McGraw-Hill News

Russians Develop Ternary Digital Computer

At the Moscow Power Engineering Institute, students have developed a ternary digital computer which has been named Setun after a river which flows by the Russian college. Instead of operating on a binary system which would use only two digits (one and zero), Setun runs on three: positive pulses, negative pulses, and zero pulses.

Ternary code, reports the Russian publication *Krasnaya Zvezda*, doubles the computer speed and cuts the number of components in half. (But U. S. designers who have looked at the ternary code for computers feel that using zero pulses can be dangerous. Loss of a pulse for any of many reasons would be recognized as a zero pulse, would result in an incorrect solution.)

Design features of the machine: 4,000 "quick action" magnetic amplifiers replace vacuum tubes; magnetic drum contains program storage, and small secondary storage (type undefined) of 162 words is also used.

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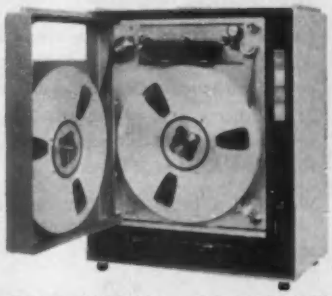

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4. A missile manufacturer uses READALL instruments in an automated "Missile Skin" milling machine.

5. These readout devices are being applied in nuclear reactor work for remote control and indication of rod position.

6. READALL instruments are now used in an electric power station monitoring system in Philadelphia.

7. READALL instruments are being used in display boards for the Air Defense Headquarters.

8. Another aircraft manufacturer uses READALL instruments in a flight simulator.

9. A branch of the military designed the READALL instruments into an airborne bomb-direction computer.

10. An aircraft systems manufacturer uses READALL instruments for display and print-out of data with a computer in a high altitude weather reconnaissance project.

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WHAT'S NEW

EUROPEAN REPORT

Soviet Productivity Plans Hit Some Snags

MOSCOW—

Although the Soviet Union is making progress toward its goal of raising worker productivity and quality of output through introduction of automatic systems, the job of closing the gap between laboratory and production line is proving troublesome.

This is the picture that came out of the July plenary meeting of the Communist Party's Central Committee, called to assess progress under the Seven Year Plan.

The Soviets see automatic control as a key factor in their determined drive to overtake, then surpass, American industry. They look to it to increase labor productivity—now only half that in the U. S.—and improve the admittedly low quality of many Soviet goods.

The party plenum was held behind closed doors so outsiders know only what was published in the Moscow press. But these reports clearly indicate the Soviets see two main problems in mechanization: to speed its absorption into the production lines of the nation and to improve reliability of the systems that are installed.

• **Progress in theory**—Some reports of progress graced the plenum meeting. V. A. Trapeznikov, director of the Institute of Automation and Telemechanics, pointed out that Soviet scientists are among the world's best in control theory. And he noted successful applications in space rockets, nuclear reactors, and in metallurgical and other industries.

Yet, in the words of Trapeznikov, "the situation in the materialization of ideas is absolutely unsatisfactory." Some evidence:

• The introduction of automatic railroad traffic control is lagging.

• 37 percent of all industrial loading and unloading is still manual.

• From 25 to 30 percent of all the machine tools in the Gorky, Leningrad, Moscow, and Chelyabinsk regions is more than 20 years old.

Most serious is the delay in putting new technology to work. According to Trapeznikov, "The time from the beginning of research to its introduction in industry usually runs into several years." Industrial plants' delay in implementing new ideas is one of the chief causes of the lag.

• **Shift the load**—Trapeznikov's own solution is to shift more of the load

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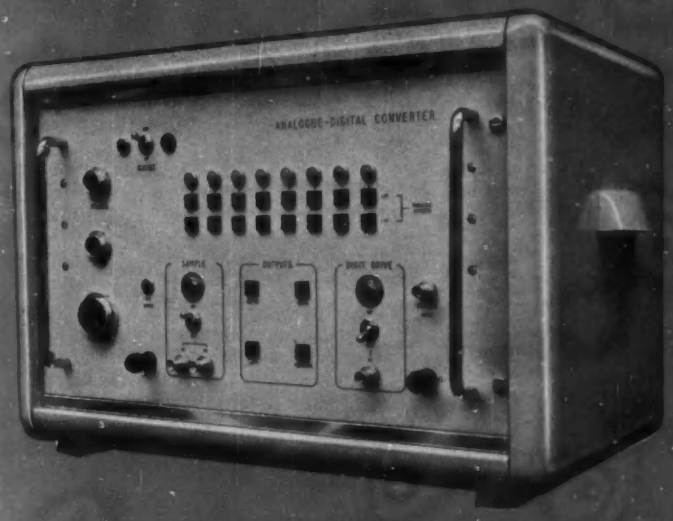

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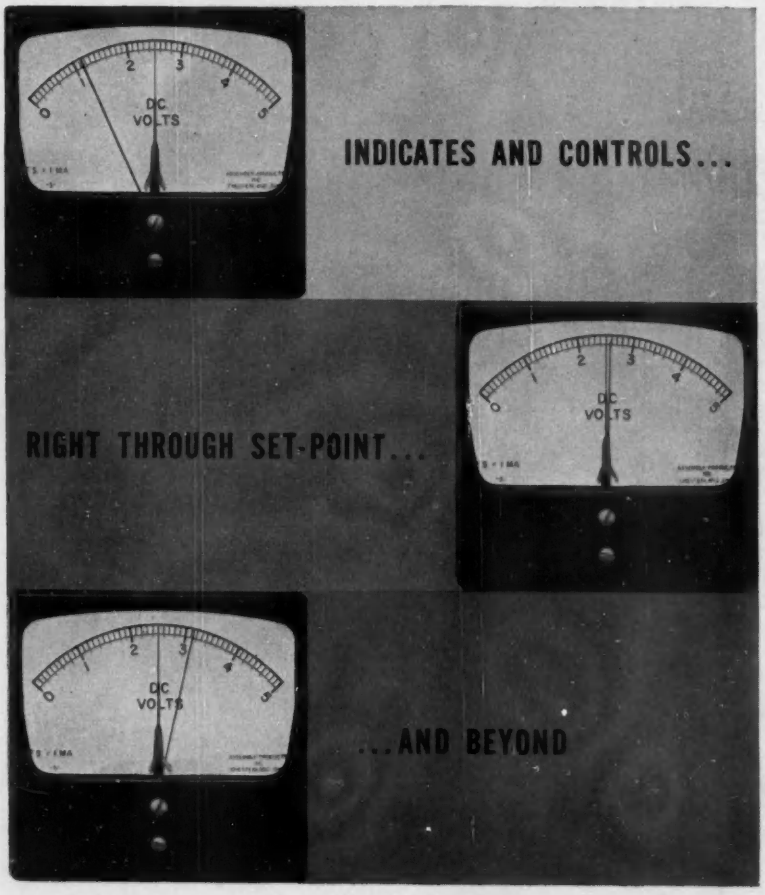

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WHAT'S NEW

for automatic systems research to experimental workshops and plant laboratories "so more thoroughly finished designs will be produced". Also, cooperation between research institutes and design offices must be increased so "it will be known beforehand where a new design will receive its embodiment." The Central Committee, in its final report, ordered planning bodies to submit proposals within six months on how this coordination should be achieved.

Responsible authorities also have been ordered to "take steps to expedite construction of pilot-model, comprehensively automatic enterprises—to disseminate their working experience in industry and transport as soon as possible".

Trapeznikov underlined the need to concentrate on more reliability in automation, along with longer service life and strength of components and wide introduction of the principles of program control.

He said the reliability problems require "profound research", that it is "the key problem and actually will decide the question whether extensive automation is to be or not to be".

• **The plenum acts**—Many observers considered the plenum disappointing because it provided few real details of how automation is progressing, particularly since automation received advance billing as one of the main topics of the meeting.

It will be months, at best, before it will be possible to judge whether any of the corrective measures ordered by the Central Committee will be fruitful. These included:

• A blanket order that planning bodies and regional economic councils "carry out measures to accelerate introduction of achievements of science and engineering in production of more advanced machines, equipment and instruments for integrated mechanization and automation". The emphasis should be on problems whose solution would bring the most substantial economic effects.

• More and better specialists should be trained.

• There should be more standardization. Planning bodies "should determine jointly the nomenclature and requirements in automatic machines and control and measuring instruments necessary for fulfillment" of automation goals, at the same time taking care to plan output of this equipment in necessary quantities.

—Ernest Conine
McGraw-Hill World News

WORKING PARTNERS

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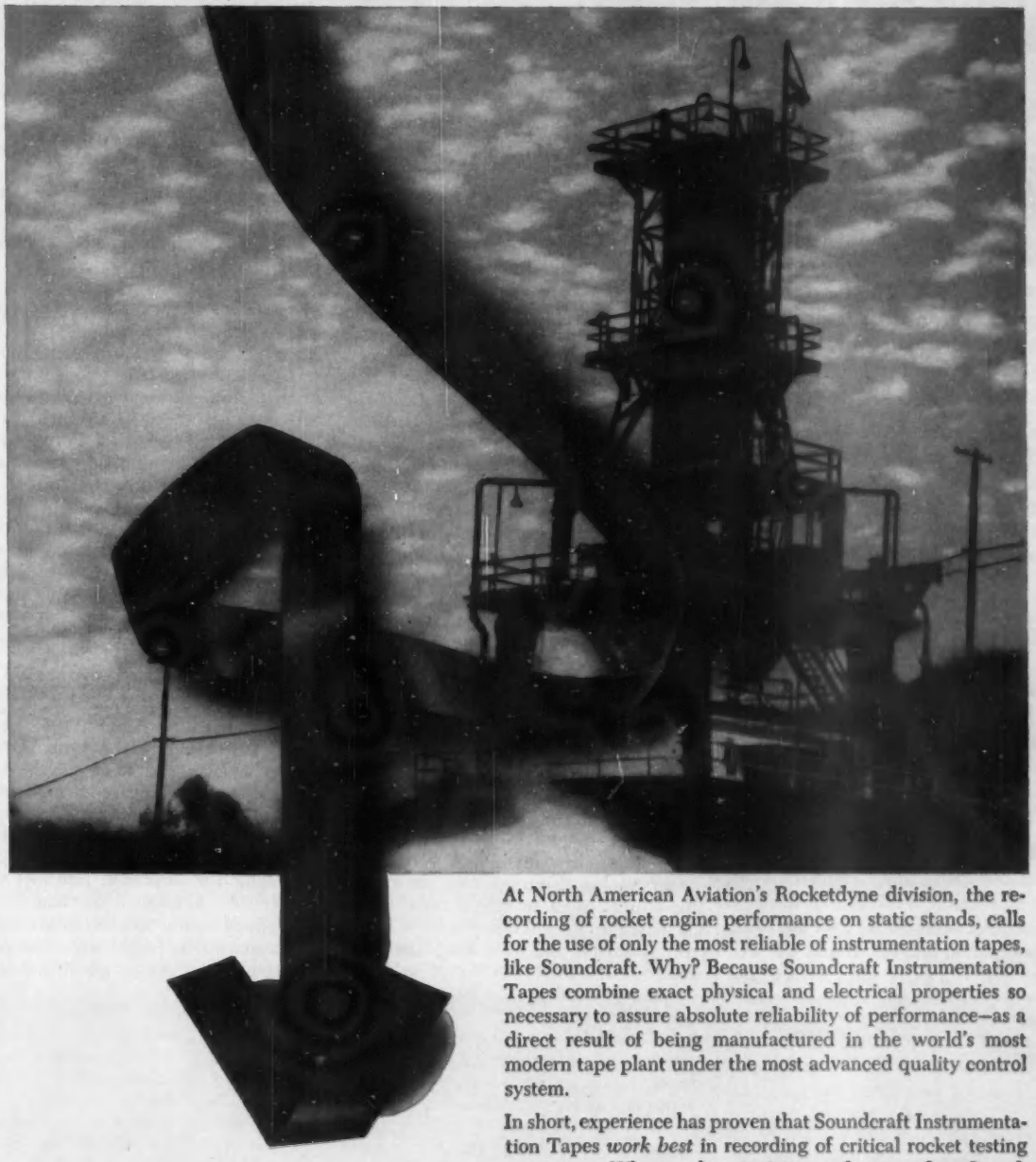

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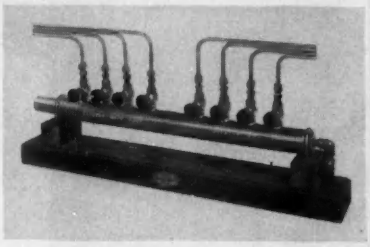

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AROUND THE BUSINESS LOOP

Will Bullard's Patent Claims Test Numerical Control?

An old line machine tool builder feels it has some basic patents in the positioning field, is offering licenses to control firms.

BRIDGEPORT, CONN.— Engineers who have been wondering just how good numerical control systems patents are may get their answer soon. The Bullard Co. of Bridgeport has initiated a series of restrained negotiations with about 20 control firms and machine tool builders throughout the U. S. and abroad to license what may be blanket rights covering the concept of numerical positioning control.

• **Behind the scene** – Bullard's strength is in its patents on Man-Au-Trol, a unique programming and positioning system for automating a vertical turret lathe, first issued in 1944. The modern version of this control uses a 50-station indexing drum for programming a machining cycle. Each station or line across the drum represents one step in the cycle and has a series of pegs or dogs that are preset by the operator. Then as the drum indexes, the pegs trip switches that control tool selection, direction of cut, feed speed, table speed, etc.

Working in conjunction with the programming drum are four positioning drums, each in effect resembling a stack of 50 circular cams. Two drums (coarse and fine) are geared directly to the drives for the X motion of the tool slide, and the other two are coupled to the Y motion. The positioning-drum cams, which are also preset in accordance with the part program, rotate as the slide moves and thus serve as a direct indication of tool position. At the end of any given tool movement, the coarse and fine cams associated with that particular step in the cycle trip switches to slow down and then disengage the slide drive.

It appears that Man-Au-Trol bears some degree of kinship to the newer crop of point-to-point positioning systems. Punched tape may replace the programming drum, and various kinds of synchros, digitizers, scales, etc. may serve the purposes of the cams.

Bullard has enjoyed great financial returns from Man-Au-Trol, reaching production peaks near 30 machines per month during the jet engine building programs. And design efforts kept pace with production: since 1944 a total of 13 patents encompassing almost 500 separate claims have been issued to protect the Man-Au-Trol concept and associated equipment.

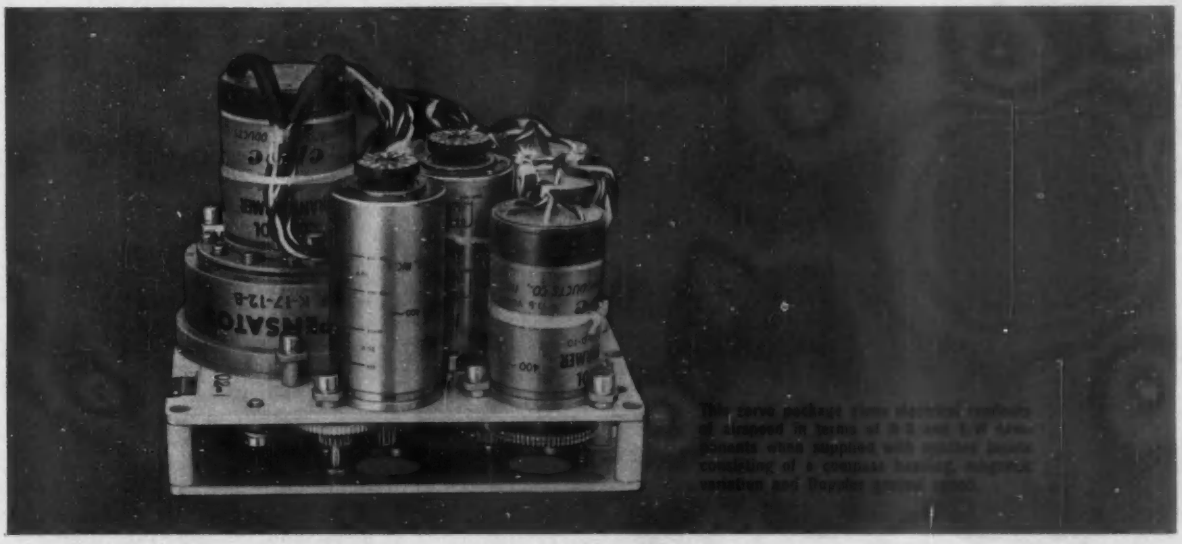
• **First action**—Bullard's first move was to send form letters to a number of the leading proponents of numerical control, such as Micro-Path, Inc., Div. of United Industrial Corp., General Electric, Compudyne Corp., and Giddings and Lewis.

The letter enclosed copies of all 13 Bullard patents and suggested that the addressee might be interested in reviewing them. It stated also that Bullard was prepared to issue non-exclusive licenses under one or more of the patents "at reasonable royalty rates".

Among the patents' claims, one reads:

> "In a machine tool, a tool head adapted to be moved in either direction along a path of travel; presettable control means having a plurality of stations, each adapted to be rendered effective by a step-by-step indexing mechanism for controlling the direction, rate and extent of movement of said head along said path; an electronic circuit adapted to cooperate with said presettable means being adapted to provide a predetermined signal voltage in said electronic circuit for each station to which it is indexed; means responsive to the movement of said tool head for nullifying said signal voltage; and means responsible to the null condition of said circuit for causing said pre-settable means to be indexed to its next succeeding station."

Bullard is awaiting action on its current invitation. As a second step, Bullard's patent lawyers have painstakingly dissected given systems and identified areas of apparent correspondence. The GE-Bullard negotia-



NOW BUY cppc QUALITY ACCURACY RELIABILITY

IN cppc SERVO MODULES

In designing and producing servo modules to *your* specifications, Clifton Precision Products Co. manufactures 95% of the parts used. What does this mean to you? It means that the same high accuracy, reliability, and quality which go into the manufacture of CPPC synchros are maintained in CPPC Systems. This one source responsibility gives you the added advantage of a continuous Quality Control activity which guarantees a high quality product.

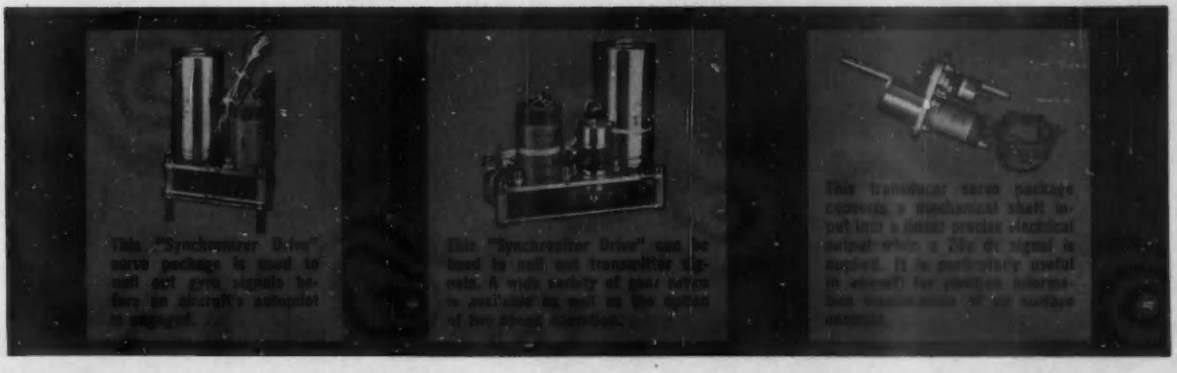
CPPC has had years of broad experience in researching, designing, developing, and manufacturing a wide variety of servo packages. A few examples of our products are shown on this page. Here at your service is a first class engineering design and manufacturing team from research through production.

Write for a more detailed facilities brochure or telephone Sales Department, MAdison 2-1000 or our Representatives.

cppc SYSTEMS DIVISION

CLIFTON PRECISION PRODUCTS CO., INC.

Clifton Heights **Pennsylvania**

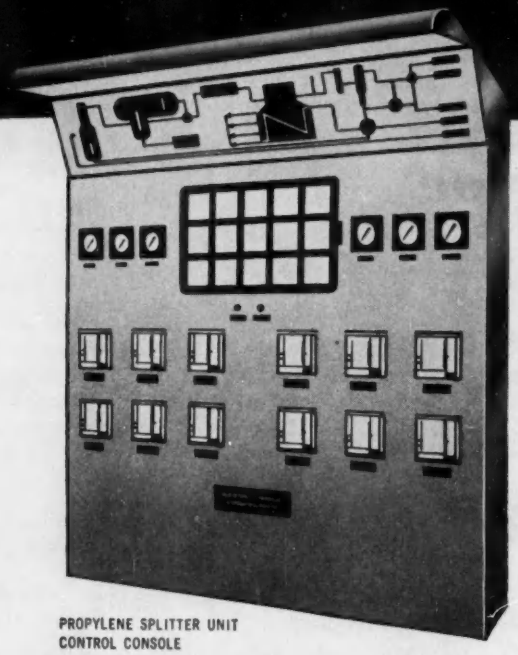


Electro-Mech

ANOTHER ELECTRO-MECH FIRST:

VIS-A-SYSTEM®

INTEGRATED CONTROL CONSOLE



PROPYLENE SPLITTER UNIT
CONTROL CONSOLE

VISUALLY AND FUNCTIONALLY INTERLOCKED:

- GRAPHIC PROCESS DISPLAY
- ANNUNCIATION EQUIPMENT
- INSTRUMENTATION
- CONTROL ELEMENTS

With this control console, Electro-Mech Corporation introduces what is literally a new dimension to control-panel design. Here for the first time is realization of complete **integration** of all functional aspects of the control console.

You are invited to see a demonstration of an actual **VIS-A-SYSTEM®** Integrated Control Console at the Annual ISA Show: Booth 1705, New York Coliseum, September 26-30.

Electro-Mech Corp., Electro-Mech Norwood, N. J.

tions, in particular, have reached this point and attempts are being made to arrange a roundtable discussion among the legal and engineering forces of both companies.

• **Environment for negotiation**—The stakes are high. E. P. Bullard, president of the company, states: "Unless we can be shown that our patents are invalid or that they do not cover other types of positioning controls, we believe that a royalty fee on the order of 3 percent of net sales price of the controls would be a reasonable basis for negotiation."

Based on surveys of the market for numerical control systems conducted by CONTROL ENGINEERING (CtE, pp. 75-77, Oct. '59) a 3 percent royalty could mean retroactive payment to Bullard of about $400,000 for 1960 alone. And a like amount might be claimed for systems sold prior to 1960.

With the output of numerical control systems mushrooming license fees could amount to between, $5 and $10 million in the next eight years, when one of the primary patents expires.

• **Bullard's team**—Leading the negotiations for Bullard is a team which includes President Bullard, who has a personal interest since he is credited with inventing Man-Au-Trol. Most of the patents are in his name.

Backing Bullard is a patent lawyer, Paul M. Geist, who was educated at Carnegie Tech and spent years in the patent office in Washington, D. C. He has been with the company long enough to personally write all 13 patents, can recite them practically from memory. To aid Geist the company retained the big patent firm of Davis, Hoxie, Faithfull & Hapgood as litigating attorneys.

• **What next?**—Despite good people, patents, and profit opportunities, Bullard has not yet decided how far it will go to push its claims. Once its position is appreciated by the numerical control companies, Bullard expects that they will agree to negotiation. It therefore believes that litigation will not be necessary.

Whatever the procedures and outcome, the negotiations of Bullard with "the punched tape people" will be watched with profound interest by control engineers everywhere.

—John D. Cooney

Crane Joins Three Units In Systems and Controls Group

Three subsidiary companies of Crane Co., Chicago based valve and

(Continued on page 260)

Here's the *only* X-Y instrument today that gives you extremely *fast response time — direct, large area recordings — 1% linearity:* the SANBORN MODEL 670A X-Y RECORDER. The capabilities of the 670A make it particularly valuable in such applications as rapid recording of diode and transistor characteristics . . . hysteresis curves for control systems, gyros, servo valves, magnetic coils; velocity or acceleration vs. vibration of mechanical elements.

Inputs to each axis are through interchangeable "850" series preamplifiers, and can range from microvolts to volts. With Model 850-1500A Low Level preamplifiers, 62.5 uv gives a 1" chart deflection; with Model 850-1300B DC Coupling preamps, 31.25 mv gives 1" chart deflection. To record one variable against time on the X-axis, the Model 670-800 Time Base Generator is also available. A plug-in MOPA is available to supply fixed frequency excitation to preamplifiers.

Recordings are made on 8" x 8" daylight-loading, ultraviolet-sensitive charts by an optical (light beam) recording system. The trace may be monitored on phosphorescent screen before recording, beam intensity is adjustable for maximum sharpness, and X and Y axes may be recorded directly on the chart. Brief post exposure in room light develops the record.

SPECIFICATIONS

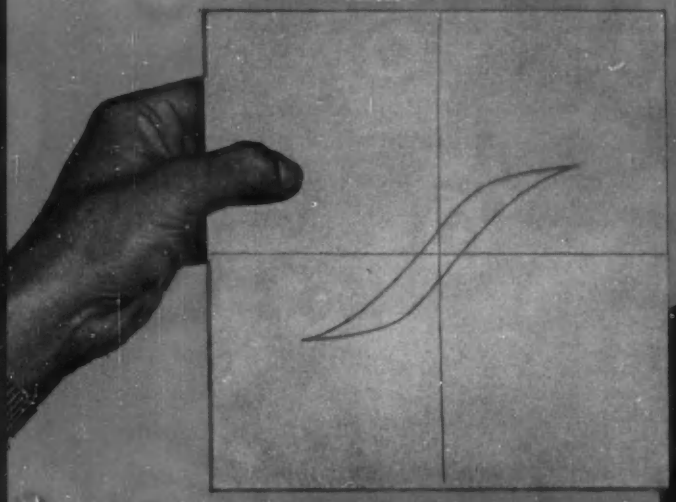
Input: single-ended or push-pull
Input Impedance: 5 megohms from each high input terminal to ground with 850-1300B preamplifier
Frequency Response: to 130 cps within 3 db at 8" peak-to-peak deflection
Sweep Rates with Time Base Generator: from 0.01 to 2 seconds
Output Drift: 0.04 inch/hour with 850-1300B
Packaging: Optional cabinet 21¼" x 20" x 20" high, or can be rack mounted in 15¾" of panel space
Power Requirements: 450 watts, 115 volts, 60 cycles AC

Ask your local Sanborn Sales-Engineering Representative for complete information on the Model 670A X-Y Recorder, or write the Industrial Division in Waltham, Massachusetts.

Record 100th-of-a-second X-Y variables directly

- *at 2500"/sec. writing speeds*
- *on 8" x 8" charts*
- *with 1% linearity*
- *from microvolts to volts*

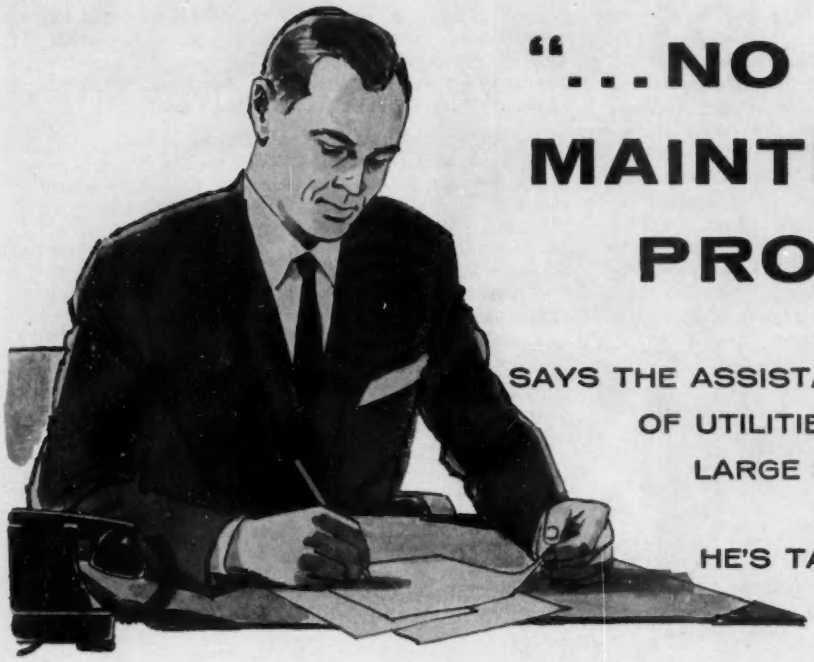
At the I.S.A. Show in N.Y.C., Sept. 26-30
Booth 1331 & 1335



HYSTERESIS IN MAGNETIC COIL. This plot of magnetomotive force vs. flux density was recorded on the Sanborn Model 670A X-Y Recorder. The complete trace was made in 1/60th sec.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Massachusetts

CIRCLE 57 ON READER SERVICE CARD



"...NO MAINTENANCE PROBLEMS"

SAYS THE ASSISTANT SUPERINTENDENT OF UTILITIES OF A LARGE STEEL MILL*

HE'S TALKING ABOUT

CONOFLOW Series LB

When approached for a comparison of maintenance costs between Conoflow LB control valves and other control valves, he exclaimed, "There are no costs of maintenance on LB valves. We've never had any trouble with them!"

Such dependable, maintenance-free performance saves a plant like this tens-of-thousands-of-dollars in downtime annually. Consider the various trades that have to be called into action or held idle when a control valve must be taken out of a line, the capital tied up in idle machines, and loss of production.

Did you ever figure out what an hour's downtime costs in *your* plant? Wherever such figures are known, the Conoflow LB control valve makes "dollars-and-sense" savings that can't be beat.

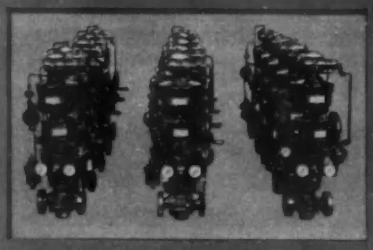
We show here only a few of hundreds of "testimonial" installations where users enthusiastically endorse Conoflow LB Valves.

Let our representative give you an actual demonstration and tell you more . . . or write today for Bulletin LB, Conoflow Corporation, 2100 Arch St., Philadelphia 3, Pa.

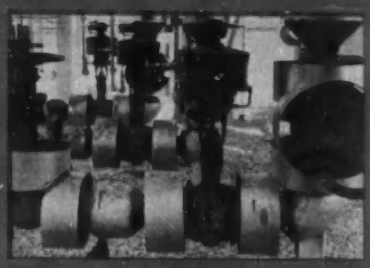
*Name on request

VISIT CONOFLOW BOOTH 1445, New York 1960 ISA SHOW, September 26-30

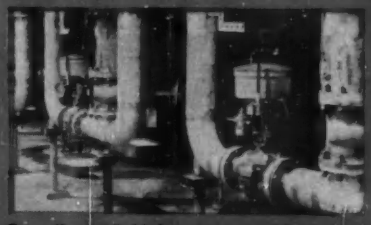
CONOFLOW CORPORATION . . .



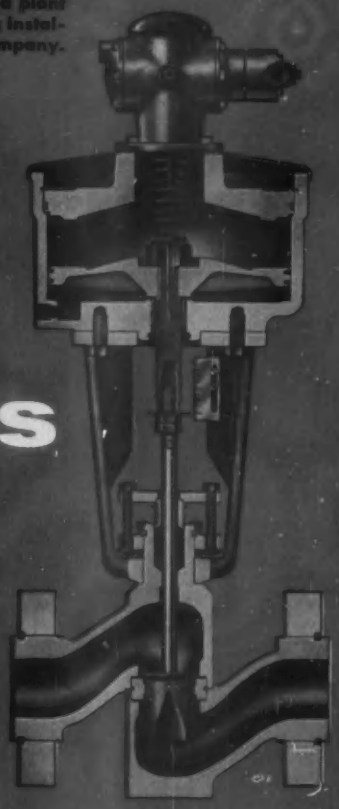
Part of a shipment of 62 Conoflow LB Valves destined for the Union Miniere du Haut-Katanga's Congo plant, one of the world's largest copper plants.



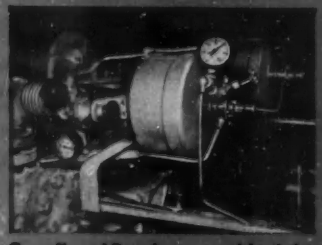
Conoflow LB Valves at Sun Oil Company's new La Verne, Oklahoma plant —a modern gasoline processing installation by J. F. Pritchard & Company.



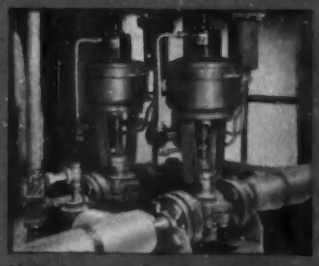
Conoflow LB Valves on a critical control application at American Cyanamid's new acrylic fiber plant in Santa Rosa, Florida.



CONTROL VALVES

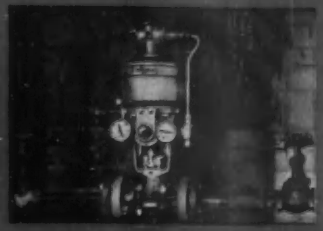


Conoflow LB valves provide tight shutoff for steam lines against high pressure differentials at the R-W Paper Company plant in Longview, Washington.



More than 600 Conoflow LB valves operate in the Lancaster, Pa. plant of Armstrong Cork Company. Valves shown have been on a temperature control service for over seven years.

This Conoflow LB valve is handling hot coal tar at temperatures to 750° F. in the Bethlehem, Pa. plant of the Barrett Div., Allied Chemical & Dye Corporation.

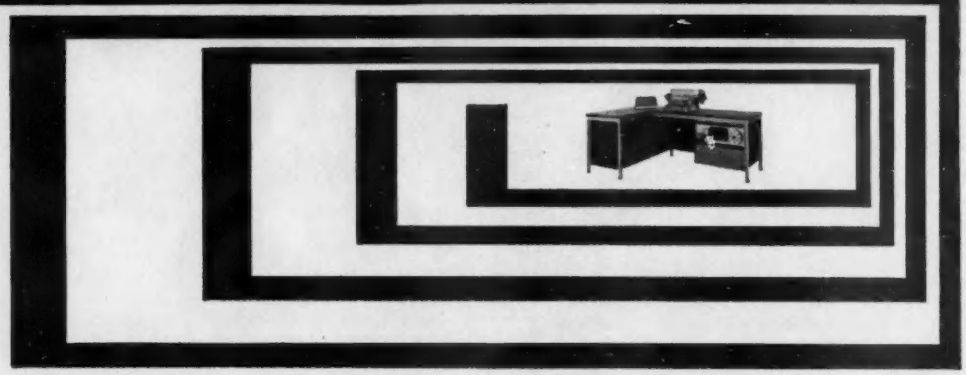


"These (Conoflow LB) are the best valves we ever found for tight shutoff on our maleic acid lines" says Instrument Foreman of a large mid-west chemical plant.

. . . FOREMOST IN FINAL CONTROL ELEMENTS

CIRCLE 59 ON READER SERVICE CARD 59

MONROBOT XI *Another Achievement from Monroe*



FROM NOW ON, *electronic computers will all be judged by this one. The* ***MONROBOT XI*** *is an all-purpose electronic computer priced and sized for the moderate-size business unit.* ***MONROE*** *has ingeniously compacted all the functions of the super-giant computer into a desk-size solid state machine any typist can operate. Despite appearances, this is no miracle, though that may be disputed by elated businessmen for whom electronic data processors had always been far too big or too costly. And to those already initiated, it brings the widely expanded benefits of decentralized electronic data processing. Astonishing how little Monrobot XI costs and how fast it will pay you back.*

See the MAN from MONROE

A DIVISION OF LITTON INDUSTRIES

for CALCULATING · ADDING · ACCOUNTING DATA PROCESSING MACHINES

Monroe Calculating Machine Company, Inc. Sales and service in principal cities everywhere. General offices, Orange, N. J.

Reeves
INSTRUMENT CORPORATION

proudly presents the

ZERO-ONE

IFG-300
Integrating Floated Gyro

CONSISTENT RELIABILITY

in production-quantity **miniature** floated gyros

with trimmed drift rate of

ONE HUNDREDTH DEGREE per **HOUR**

Designed-in reliability and the most precise production techniques have combined to produce the new ZERO-ONE Gyro. The first in a new series of IFG-300 integrating floated gyros, the ZERO-ONE is a proud achievement in the long line of gyro developments by REEVES.

The combination of high reliability and extreme accuracy make the ZERO-ONE Gyro the ideal choice for guidance and stabilization systems where guaranteed performance is paramount.

For complete specifications, write for data file 109.

Qualified engineers seeking rewarding opportunities in these advanced fields are invited to get in touch with us.

TYPICAL SPECIFICATIONS

Trimmed Drift Rate: 0.01 degrees/hr

Angular Momentum: 300,000 c.g.s. units

Damping: 300,000 c.g.s. units

Nominal Signal Generator Sensitivity: 10 mv/mr @ 50 ma, 400 cps

Torque Generator Sensitivity Range: 0.05 to 3.0 degrees/hr/ma^2

Time Constant: As low as 0.4 msec.

Mass Unbalance: 0.4°/hr/g

Anisoelasticity: 0.003°/hr/g^2

Dimensions: 1.8 in. x 2.75 in.

Reeves
INSTRUMENT CORPORATION

REEVES INSTRUMENT CORPORATION

A Subsidiary of Dynamics Corporation of America • Roosevelt Field, Garden City, New York

7RV60

Now, with one instrument, you can

1 mv at

hp 411A Voltmeter

Specifications

Voltage Range: 10 mv rms full scale to 10 volts rms full scale in seven ranges. Full scale readings of 0.01, 0.03, 0.1, 0.3, 1, 3 and 10 volts rms.

Frequency Range: 500 KC to 1,000 MC with accessory probe tips.

Accuracy: 1 MC to 50 MC, ±3% of full scale; 50 MC to 150 MC, ±6% of full scale; 500 KC to 1,000 MC, ±1 db.

Meter Scales: Two linear voltage scales, 0 to 1 and 0 to 3, calibrated in the rms value of a sine wave. Db scale, calibrated from +3 to −12 db; 0 db = 1 mw in 50 ohms.

Galvanometer Recorder Output: Proportional to meter deflection, 1 ma into 1000 ohms at full scale deflection.

Probe Tip Furnished: Pen type Probe Tip, 500 KC to 50 MC. Shunt capacity less than 3 picofarads at 1 volt, less than 4 picofarads at 10 mv. Shunt resistance depends on voltage and frequency.

Other Probe Tips Available at Additional Cost: VHF Probe Tip, 500 KC to 250 MC. Shunt capacity less than 1.5 picofarads at 1 volt, less than 2 picofarads at 10 mv. Shunt resistance depends on voltage and frequency.

Type N "Tee" Probe Tip, 500 KC to 1,000 MC. SWR less than 1.15 when terminated in 50 ohms.

BNC Open Circuit Probe Tip, 500 KC to 500 MC.

100:1 Divider Probe Tip, 500 KC to 250 MC. Division accuracy ±1%. Shunt capacity 2 picofarads. Shunt resistance depends on voltage and frequency.

Power: 115/230 volts ±10%, 60 cps, 35 watts.

Price: hp Model 411A $450.00.

Data subject to change without notice.
Prices f.o.b. factory.

instantly measure

1,000 mc!

or any rf voltage 1 mv to 10 v, over the very broad bandwidth of 500 KC to 1,000 MC. Accuracy is higher than any similar voltmeter known. Measuring is as simple as "touch and read" on the big, high resolution linear scale. Annoying thermal drift errors are eliminated.

Think of the times you would have liked to measure —with utmost accuracy—millivolts at rf frequencies.

Now you can do it, easily and dependably, with one compact instrument—the new ℌ 411A VTVM.

This remarkable instrument has true linear operation—no correcting networks are required.

It has high temperature stability—negligible accuracy change from 10° to 40°C.

Such performance stems from a unique, ℌ-developed circuit involving feedback applied to a diode-detector-dc amplifier arrangement; and further involving instantly replaceable, encapsulated, *matched* diodes!

Truly, this circuit has to be seen and operated to be believed. Write for a detailed description (ask for ℌ 411A Data Sheet) or better yet, call your ℌ rep for a bench demonstration.

And how about these extra features: (a) the matched diodes are protected against burnout (b) probe is temperature compensated for low drift (c) ℌ-developed amplifier photochopper eliminates contact noise, guarantees high sensitivity, zero-drift freedom (d) extra probe tips include units for high frequency measurement, for measuring *on* as well as *at termination* of coax transmission lines, and a capacity divider increasing 411A voltage capability to 1,000 volts.

Why put up with complex, cumbersome instruments? Get a new 411A into action on your bench now!

HEWLETT-PACKARD COMPANY
1051H Page Mill Road, Palo Alto, California, U.S.A.
Cable "HEWPACK" DAvenport 6-7000
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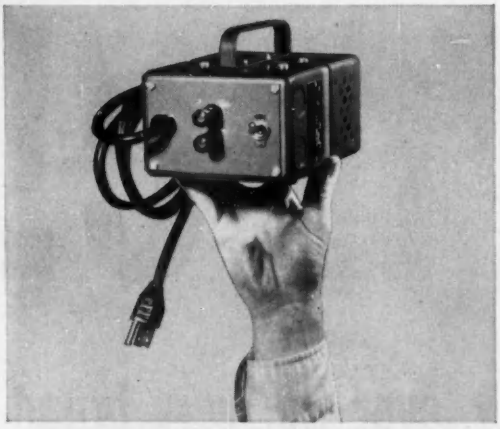
Take your voltage supply where you need it with Sola's portable sources of regulated voltage



Portable filament transformer insures stable test conditions

This static-magnetic voltage regulator, with capacity of 30va, provides a stabilized output of 6.3 volts, automatically and continuously regulated within ±1% despite line voltage swings between 95 and 130 volts.

Since no variants are introduced by line voltage dips or surges, your experimental and test equipment is given a consistent reference datum against which it can yield reliable data on other variables.

The unit provides a high degree of isolation between input and output. Simple, rugged design eliminates moving parts, replaceable parts, manual adjustments, routine inspection and maintenance.

Handy in the laboratory or at the shop bench, it plugs into any a-c wall or bench outlet, and provides an on-off switch and output jacks.

Write for Bulletin CVF

Portable Solavolt power supplies give regulated a-c and d-c voltage for laboratory and test work.

A-C and D-C Solavolts regulate output within ±1% for line voltage variations as great as ±15%, with a response time of 1.5 cycles or less.

Output of the a-c model is fully adjustable from 0 to 130 volts, with less than 3% total rms harmonic content. This makes it ideal for instrument calibration, testing, or any operation involving elements sensitive to wave shape.

The d-c model consists of a special type of Sola Constant Voltage Transformer, semiconductor rectifier and choke. Ripple voltage is held within 1% rms at full load.

Solavolts have no replaceable parts, require no routine maintenance. They are portable for bench use, or may be mounted on a standard 19-inch relay rack.

Write for Bulletin CVL/DCL

Portable Televolt improves performance of TV sets, radios, hi-fi, tape recorders

This static-magnetic voltage regulator improves television reception by correcting line voltage variations which often cause picture flicker and distortion. It also stabilizes voltage for improved performance of high-fidelity amplifiers, radios and tape recorders. The unit regulates within ±3% of nominal for input voltages between 95 and 130 volts, to give a nominal fixed output within the range of 115-120 volts. Requires no installation—merely plug it in and forget about it. The compact Televolt is automatically switched on or off by a relay whenever the equipment power switch is operated.

Write for Bulletin 26J-CVA

SOLA

SOLA ELECTRIC CO. BPC

Sola Manufactures: Constant Voltage Transformers, Regulated DC Power Supplies, Constant Wattage Mercury Lamp Transformers and Fluorescent Lamp Ballasts

A Division of Basic Products Corporation

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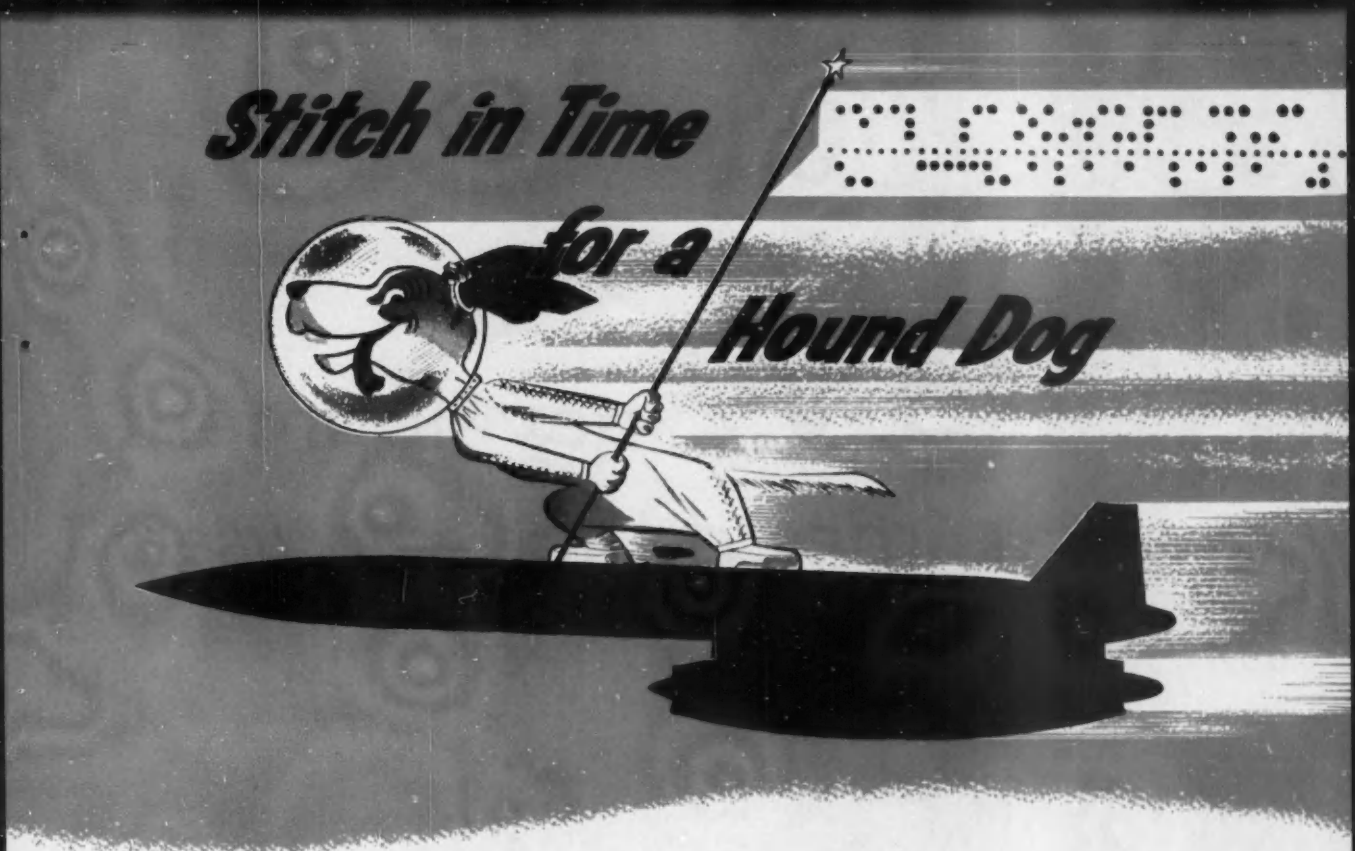


New Tally Tape Console cuts punched tape preparation time by 600% on Hound Dog missile

Last fall, the first production model of the new Tally Tape Console was delivered to North American Aviation's Missile Division to speed the preparation of punched paper tapes. The tapes in turn program both production and preflight missile checkout systems on SAC's Hound Dog missile.

Before the Tally Tape Console was installed North American Missile Division engineers took 30 hours to make and absolutely verify a 400-foot programming tape. To make and absolutely verify a duplicate copy of the tape required an additional 75 minutes.

The Results

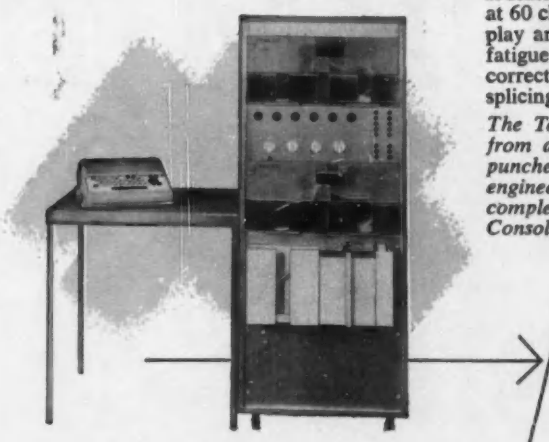
Now, North American Missile Division engineers using the new Tally Model 150 Tape Preparation and Editing Console make 400-foot tapes in three to four hours. Duplicate tapes are made in only 37 minutes. And Tally tapes are *guaranteed* error free.

Tally/Seattle is pleased to have played a significant role in North American's pace setting GAM-77 program which took only thirty months from design to flight of production models by SAC crews.

Tally's Tape Console simplifies and automates punched paper tape production

It features tape-to-tape duplication and verification at 60 characters per second. A keyboard visual display and shift register reduces error and operator fatigue in both punching and verifying modes. Tape corrections can be made without overpunching or splicing.

The Tally Tape Console is another new product from a creative engineering team specializing in punched paper tape technology. Your nearby Tally engineering representative can provide you with complete technical information on the Tally Tape Console or you may write directly to Dept. 21

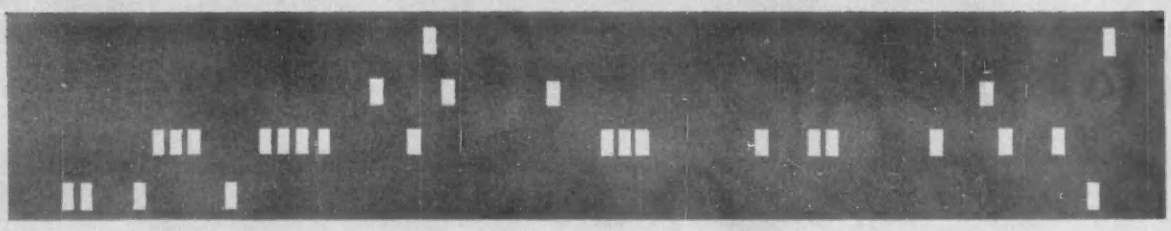


TALLY

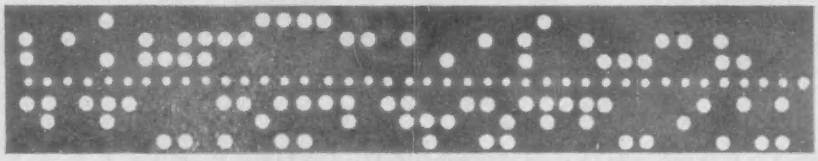
REGISTER CORPORATION

1310 Mercer Street
Seattle, Washington
Phone: MAin 4-0760

CIRCLE 65 ON READER SERVICE CARD



a new development of vital importance—*to users of punch cards and tape*

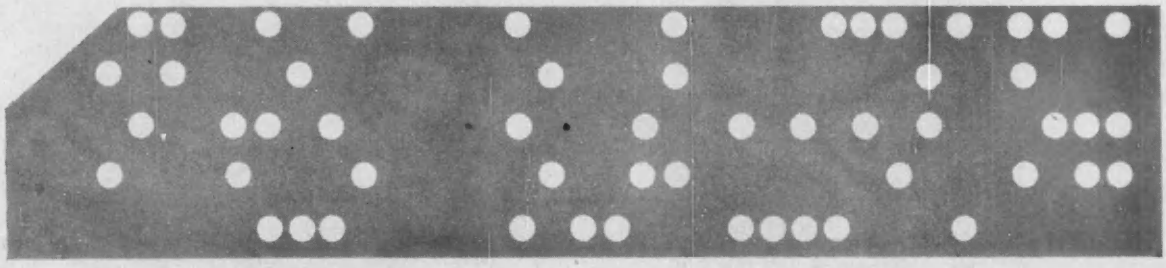


The Dobeckmun Company is now successfully laminating foil, Mylar* and paper in varying combinations to produce tape and card stocks of extremely high dimensional stability and strength. They have proven to be particularly valuable in complex control and programming systems that demand absolute fidelity of every component part.

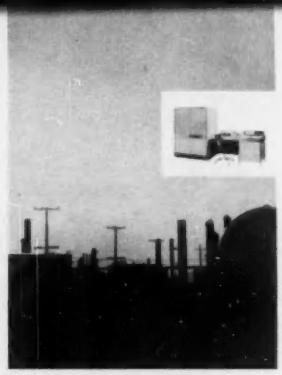
If you have special tape or card stock requirements, we shall be delighted to work with your development people in producing a special material. We feel confident that somewhere within the framework of our skills and diversified products we can be of service to you. Write for brochure of complete details.

DOBECKMUN

The Dobeckmun Company, a Division of The Dow Chemical Company, Cleveland, Ohio • Berkeley 10, Calif. • Offices in most principal cities.
*MYLAR IS A REGISTERED DUPONT TRADEMARK



DAWN OF A NEW ERA IN INDUSTRIAL PROCESS CONTROL



Why the LIBRATROL-1000 COMPUTER excels at industrial process control

PACKAGING FEATURES

Sealed cabinet keeps out dust and corrosive fumes. Designed for ease of maintenance. Refrigerated cabinet maintains the even-temperature environment that is so important to reliability of electronic components. Engineered for vibration resistance.

INPUT-OUTPUT FEATURES

Quick-access loop speeds input of transducer data and output of commands to actuators. Input and output can take place while computations continue. The number of transducers and actuators which may be integrated into a LIBRATROL®-1000 process control system is limited only by the type of program the application requires.

OTHER IMPORTANT FEATURES

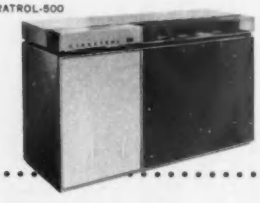
Sequencing is by computer command and is thus changeable by program. Complete random sequence, fixed sequence, or single channel operation, at programmer's option. 8000-word memory. Binary number base. Serial mode of operation. 31-bit words plus sign. Two-address operation.

Only LIBRASCOPE offers a choice of two computer systems...

The LIBRATROL®-500 is a versatile but less expensive system... ideally suited to helping you learn your process requirements... developing a program for long-range conversions to automatic control... or fully handling on-line situations not requiring the special environmental packaging and high-speed capacity of the LIBRATROL®-1000. Either is available on a variety of purchase or lease arrangements.

LIBRATROL-1000

LIBRATROL-500



Can the new era in Automatic Process Control mean significant improvement in your Company's operation?

Find out. Write for the new Libratrol brochure with specifications and operating information. Or better still, request consultation now with a Librascope Systems Engineer versed in the control requirements of your industry.

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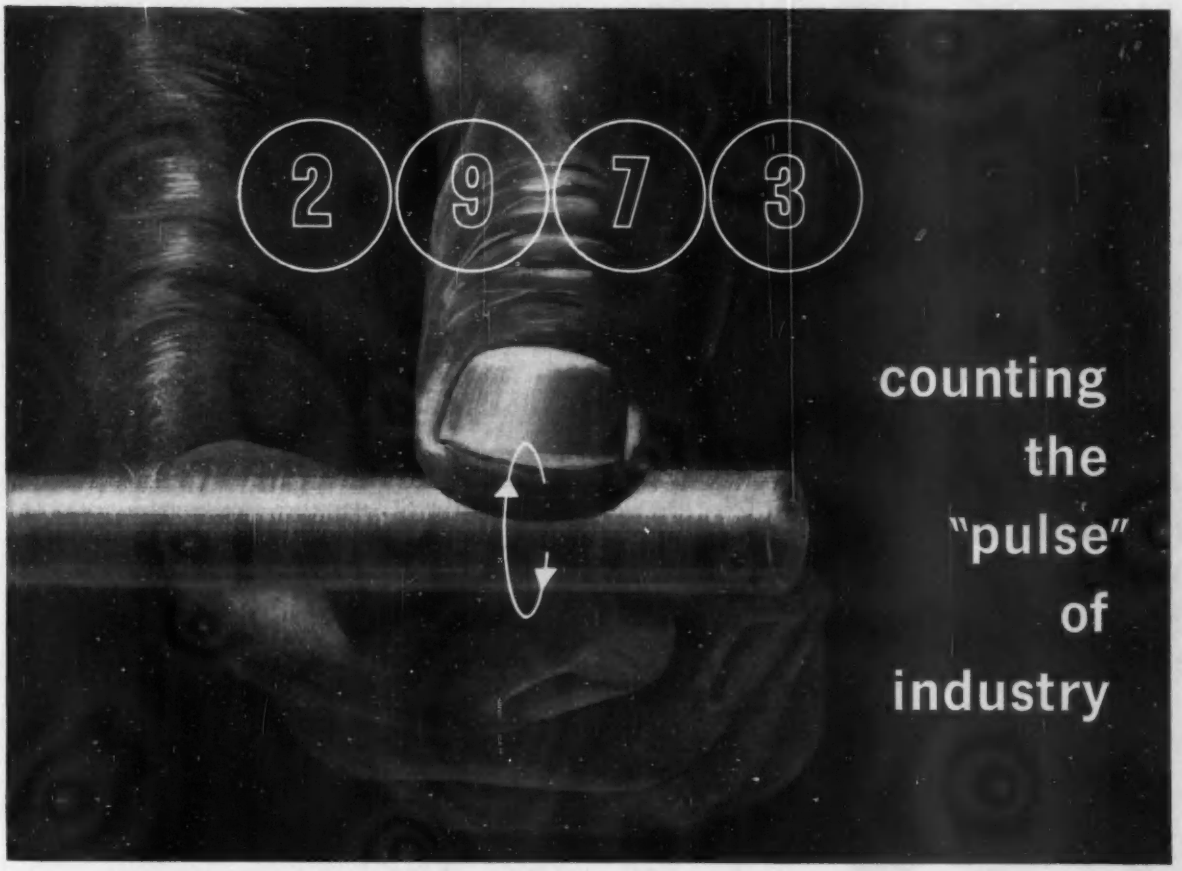
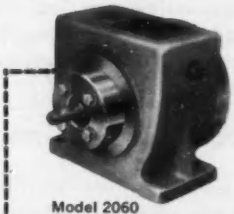
GLENDALE 1, CALIFORNIA

Computers that pace man's expanding mind



...through MERIAM·ILS electronic speed indicating systems



Model 2060
Explosion-proof
Tachometer Pickup.
U. L. Approved.

Model 1313
Remote Electronic
Frequency Counter

Model 1313P
Digital Readout

MERIAM engineers are dedicated to the design and manufacture of speed indicating instruments. Their achievements already include outstanding accomplishments in the fields of automation, jet engine development, automobile components, conveyor control, pumps and electric motors. This is why we say . . . specify a Meriam matched system of pulse pickups, counters and digital readouts from a wide variety of units which have been developed to meet the needs of virtually all applications. Meriam instruments are constructed for heavy-duty industrial use and, if required are available with explosion-proof housings for applications in hazardous areas.

THE **MERIAM** INSTRUMENT CO.

ILS ELECTRONIC DIVISION

Send for detailed specification charts for Meriam Electronic Speed Indicating Systems.

The Meriam Instrument Co. 9086-MI
I L S Electronic Division
10903 Madison Avenue, Cleveland 2, Ohio

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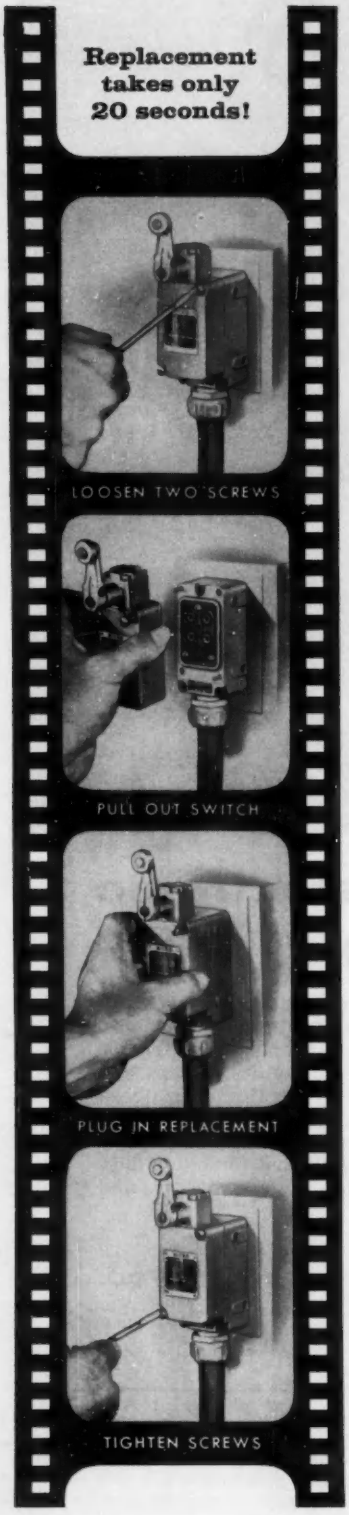


HOW MICRO SWITCH "Plug-in Limit" switches keep selling your machines...

The limit switches you specify on your machines can be salesmen or "sore spots." That's why more and more machine tool builders are depending on MICRO SWITCH reliability. And, MICRO now offers the most complete line of "Plug-in Limit" switches in the industry. These timesavers offer many special advantages when you specify them for your equipment:

1. MEASURABLE DOLLAR SAVINGS

Actual case histories prove the 20-second replacement time sometimes saves hundreds of dollars in production time over ordinary limit switches. The switching unit plugs in like a radio tube. Receptacle need not be removed. Your customers will appreciate this reduction of down time.

2. NINE DIFFERENT ACTUATORS

The one receptacle is designed for any of the nine styles of actuators. Flexibility for the design of your machine; adaptability later if necessary.

3. AUTOMATIC STATION CONTROL

Your customer will be able to automatically disconnect any station on his line by simply pulling out the correct MICRO "Plug-in Limit."

4. BEST SEALS AVAILABLE

The "O" Ring and gasket seals on these switches are the best available. Greater reliability for your machines, important because with customers, every actuation of a switch is a test of your equipment.

See the Yellow Pages for the location of the nearby MICRO SWITCH Branch Office and ask for the full story on how "200LS" Series "Plug-in Limit" switches can help sell your machines. Or, write for Catalog 84.

75th YEAR HONEYWELL PIONEERING THE FUTURE

MICRO SWITCH Precision Switches

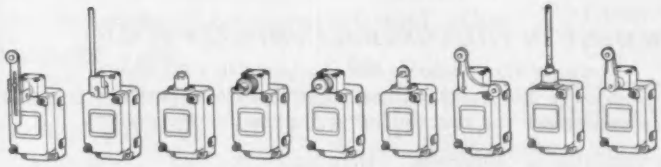
The "200LS" line has rugged terminal blocks with heavy No. 8 terminal screws for easy wiring and sturdy, molded barriers to protect plugs from damage. Operating head mounts in four positions.

5. FLEXIBLE MOUNTING

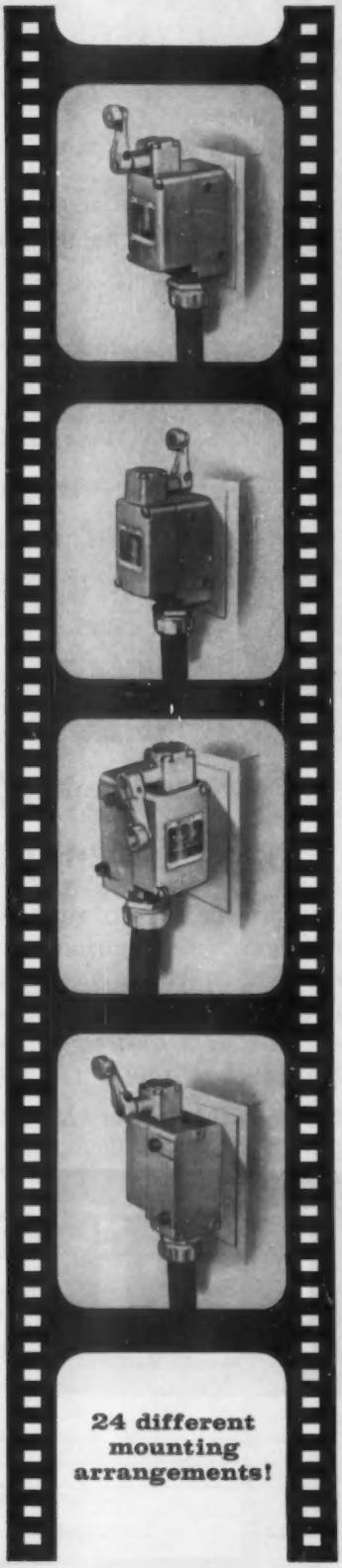
May be side-mounted or back-mounted for a possibility of 24 different mounting arrangements.

6. WIDER SELECTION

MICRO SWITCH offers many variations to fit specific needs. All have the same receptacle size for easy interchangeability. There's sure to be a model that fits your design needs.



MICRO SWITCH . . . FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls Limited, Toronto 17, Ontario



Honeywell
MICRO SWITCH Precision Switches

Latest news about the 609

In 1960... Four ISI 609's now serving the process and power industries. Four more to be delivered this year for Chemical process analysis and production control... Natural Gas dispatching... Electrical Utility power generation

Why customers are buying the practical 609 INFORMATION AND COMPUTER SYSTEM

The 609 is exceptionally versatile—You get simultaneous on-line automatic control and off-line analytical computation. Multiple programming is a practical reality in the 609 through automatic priority interrupt.

Expandable System—Optional disc memory provides additional quick access working storage available in modules of various word capacities.

On-Line Control Unit provides fast (2.80ms) multiplication and square root—contains input-output controls for on-line communication with the process to be monitored and controlled.

Index Registers—An extra digit in *every* instruction word makes it possible for every command to function as an index register.

Both the operator and the computer engineer can use this advanced system. A direct, plain English Input Control Panel enables the operator to change or read out any process data constants or scanned variables.

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BEST INVESTMENT IN THE CONTROL COMPUTER FIELD

The solid state, reliable 609 is applied to your objectives by ISI—a company with 10 years of experience in engineering practical data systems for the power and process industries.

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It can, with modification, scramble video signals . . . or ride inside a satellite or missile, converting temperature and other environment data.

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It can, with equipment employing this technique, speed billing and payroll assignments now handled by digital means . . . digitize target information faster, enabling radar control systems to intercept or guide missiles or aircraft more accurately . . . help analyze an oil refining process, or the trajectory of an ICBM, in millionths of a second.

It is the most recent example of Raytheon Company Communications-Data Processing Capability.

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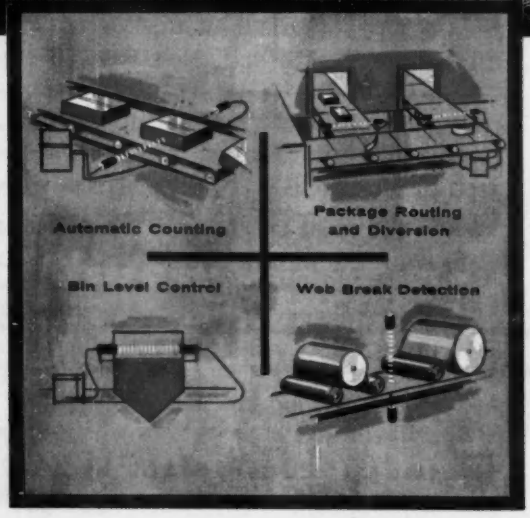
a new dimension in automated controls

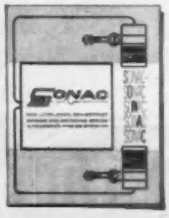


SONAC ULTRASONIC,

NON-CONTACT SENSING AND SWITCHING SYSTEM

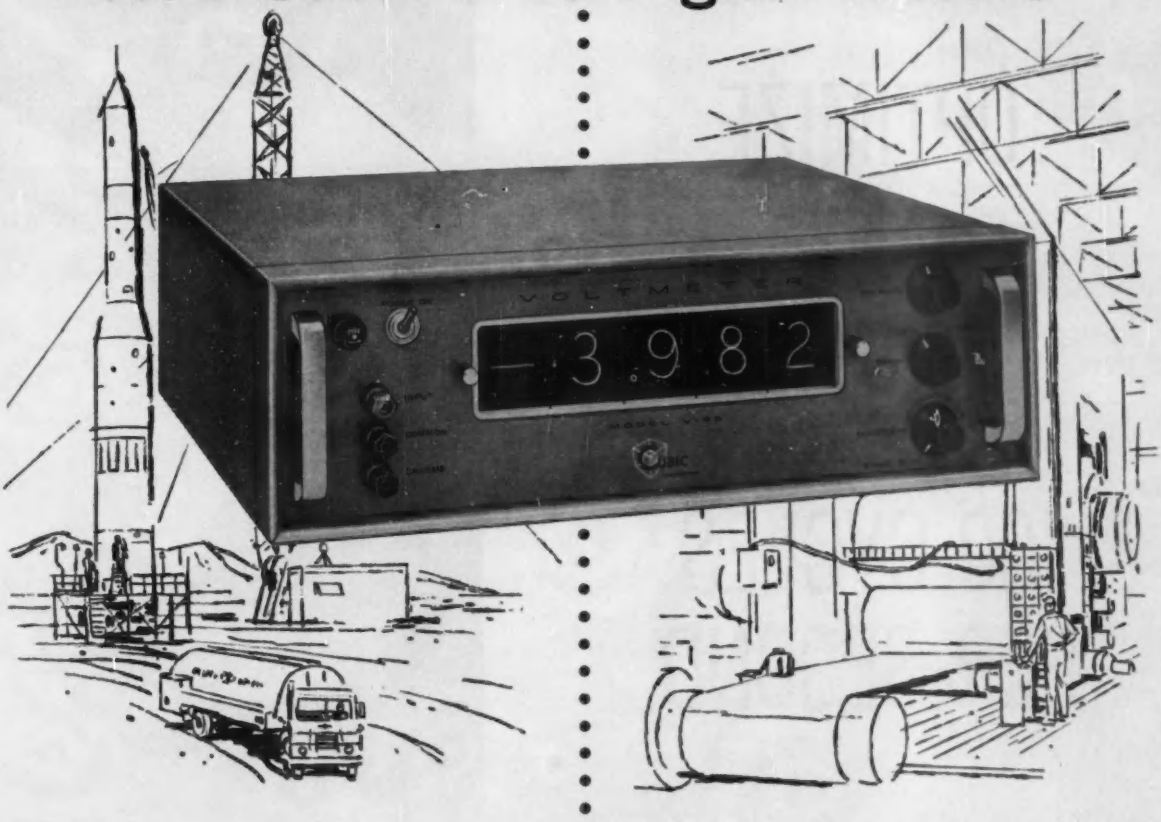
Before Sonac, sensing and switching control systems which involved breaking a beam of energy were limited by vibration, dust, smoke, steam, air contamination and too much or too little light. Sonac's ultrasonic energy "beam" is completely free of these limitations. The acoustic lens on Sonac sensors can actually be painted without affecting performance. Utilizing high frequency sound also means there are no lamps to burn out. Savings in replacement parts and maintenance time often means Sonac pays for itself. Sonac is completely transistorized, providing you with a rugged, dependable electronic circuit.

These are just a few of Sonac's many uses. Optional equipment includes reflectors for precision beam and positioning control, and coupler assemblies for use with flexible tubing for remote sensor locations. This descriptive booklet will be sent to you on request.



DELAVAN Manufacturing Company
WEST DES MOINES • IOWA

New Cubic V-45 Digital Meters



Priced for Industry! Proven for Defense!

SPECIFICATIONS

Absolute accuracy: 0.02% ±1 digit (rms sum of system tolerances)

Input: Floating or grounded, from front panel connections.

Input impedance: 10 megohms at balance

Input filter: 60 cps rejection

Ranges: Manually selected, 10% expanded range

Low	±0.000 to ±10.999 vdc
Mid	±00.00 to ±109.99 vdc
High	±000.0 to ±1099.9 vdc

Sensitivity: 1 millivolt

Sensitivity control: continuous from 1 digit to 10,000 digits, with standby lockout.

Power input: 105-125 vac, 50-1000 cps, 20 watts

Dimensions: 19" wide x 5¼" high x 15½" deep, rack or bench mounting, with dust-proof switch and bridge section.

Now, at last, the top quality and dependability of Cubic digital voltmeters are available in a meter priced for the industrial market. It is the new four-digit V-45 Digital Voltmeter, fully transistorized, accurate, economically priced.

The practical manager recognizes the costliness of operator errors through misreading and misinterpretation. These errors occur daily on the production line, in quality control, testing and receiving inspection. Alert managers are continuously seeking instrumentation which will eliminate the human element in measurement procedures.

The new Cubic Model V-45 Voltmeter is the answer. It offers the precision expected from custom-built equipment and covers the full d-c range from 1 millivolt to 1099.9 volts. It is rugged enough for operation in any industrial environment. Like all Cubic digital voltmeters, the V-45 features the proven reliability and accuracy of transistor-driven stepping switches.

Write for more information to Dept. CE-1, Industrial Division, Cubic Corporation, San Diego 11, California.

V-45 . . . the economy meter in a quality line, price $940.00

cubic

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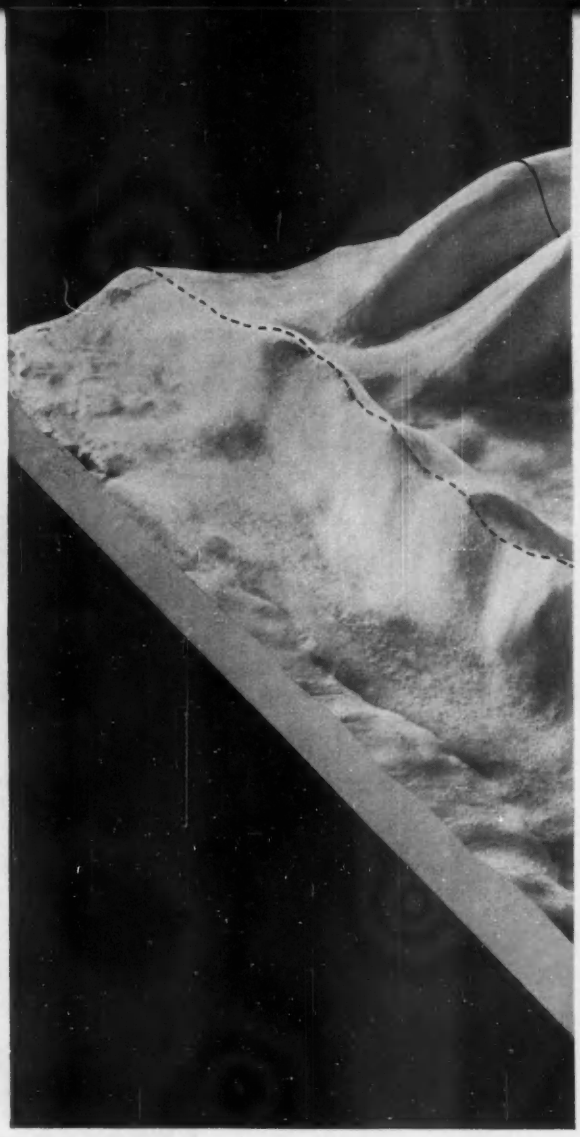
OPTIMIZE ANY MODEL at 100 CYCLES PER-SECOND

WITH DYSTAC COMPUTERS



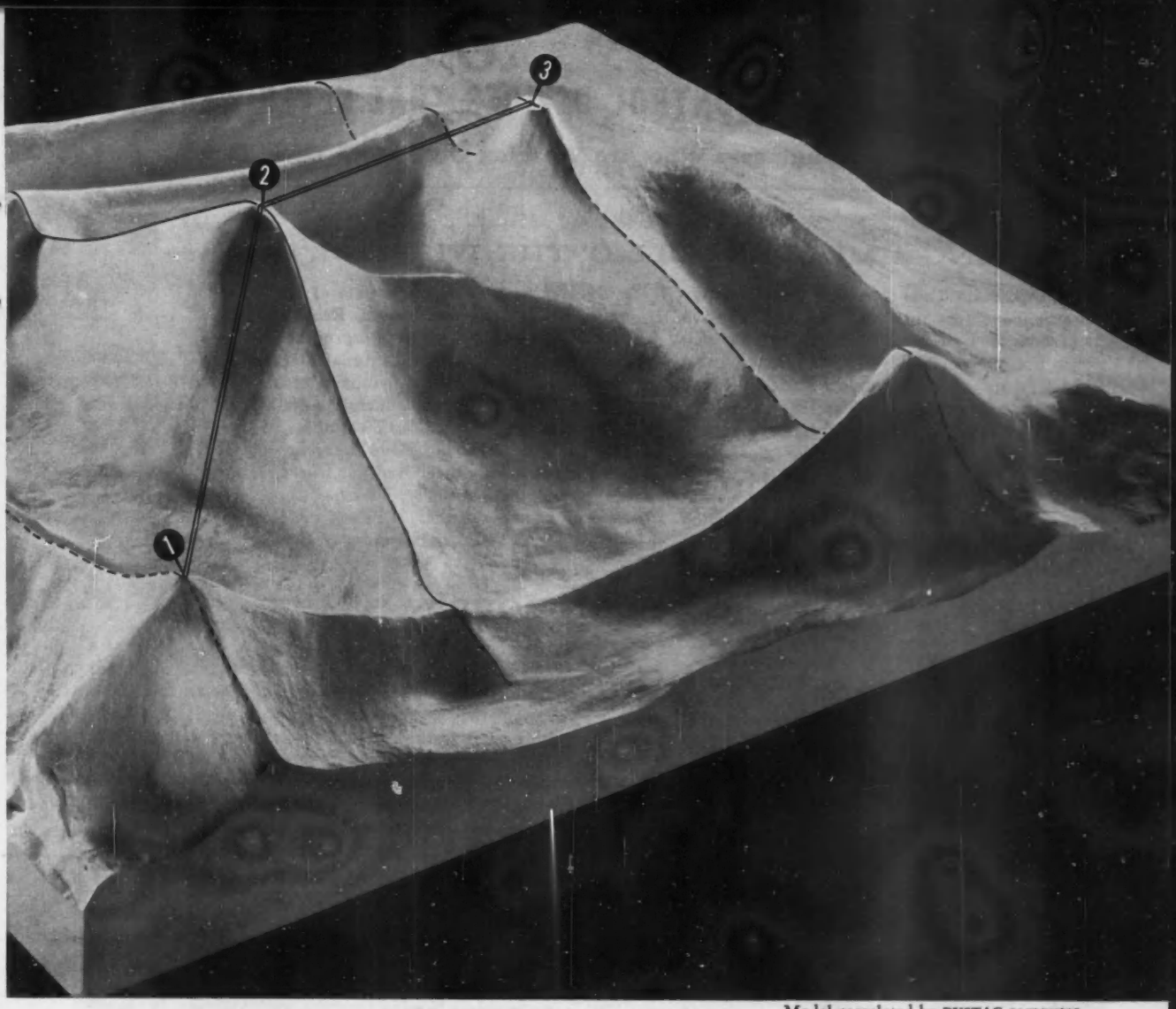
Whether your problems are dynamic or static, covering costs, design, or production control in: Operations Research, Chemical Kinetics, Aerodynamics, Structures, Astrophysics, or Hydrodynamics, DYSTAC computers can solve them faster, more accurately, and more economically than any other computer.

The reason is simple: DYSTAC is a new kind of computer. It combines the best features of both analog *and* digital machines.

Only DYSTAC by CSI incorporates high-speed repetitive operations with dynamic storage of analog data to an accuracy of 0.01% and with a time-base accuracy of ±0.5 microseconds.

DYSTAC provides unique time-sharing of computer components and high speed reiterations. These features make possible economic and rapid solution of complex problems that have required too many computer components, or too long a solution time, to be considered practical for either digital or analog machines. And you can expand the number of operational amplifiers by a flick of a switch which converts the precision Dynamic Memory units into Fixed and Summing Integrators.

$\left(\frac{\delta a}{\delta t}\right)$ - - - - - - -	This curve describes the design parameters for the entire process, with the maximum design factor occurring at point (1).
$\left(\frac{\delta b}{\delta t}\right)$ ———	This curve describes the profitability of the process. Note peak (2), where maximum profitability occurs.
$\left(\frac{\delta c}{\delta t}\right)$ - — - — -	This curve shows the product quality variation. Maximum quality plateaus at point (3).
❶ ❷ ❸ ═══	Optimization for the entire process is achieved by operating along points (1), (2), (3).



Model correlated by DYSTAC computer

60-SECOND SOLUTIONS OF EVEN THE MOST COMPLEX PROCESS PROBLEMS WITH DYSTAC

The problem of optimizing feed stocks and operating conditions in chemical kinetics problems have defied continuous automatic solution. With any computer, other than DYSTAC, solutions are invalid as they require oversimplifications. DYSTAC computers solve these problems by least mean square procedures at *high speed* and with a *minimum of components*. Accuracies are held to ±0.05%. Send for complete 26-page report entitled *"Correlation and Optimization of Chemical Kinetics Models"*.

20-SECOND SOLUTIONS FOR THESE PROBLEMS

- multi-dimensional partial differentials (steady state or transient)
- sequential, successive solutions for algebraic matrices at 60 to 100 cps
- definite integral calculations
- multiple integrals and partial differential equations

...or any combination of these problems.

Write for complete details on how DYSTAC computers can work for you.

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JOURNAL OF APPLIED CONTROL DEVICES THAT NEVER WEAR OUT

For Control Engineers Who Are Wearing Out Before Their Time

FREEZING A MOLTEN WILL-O'-THE-WISP (to ±¼° at 2200°F)

Pittsburgh Plate Glass Company freezes molten glass temperatures at 2200°F to within ±¼° as it extrudes fiber glass so fine that 1700 miles of it weigh but one pound! How? PPG has selected CPM-1 Temperature Controllers made by Hagan Chemicals & Controls, Inc. The Hagan systems (over 200 of them have been ordered) not only set a new order of uniformity for glass fiber diameters, but are virtually wear-proof. They achieve this doubly profitable result by use of static control elements: there are no moving parts, and only one vacuum tube device in the entire system! An integral part of the CPM-1 unit is a CONTROL Proportioning Reactor with six control windings. It receives a proportional signal, a reset signal and a rate signal, and provides both current limiting and manual control. *"Rugged and able to handle multiple signals, yes," said Hagan engineers, "but what about sensitivity?" When we showed them the proportioning reactor's 2-milliampere windings, there were no more questions. However, we'll be happy to answer any you may have.*

Figure 1. Hagan CPM-1 Temperature Controllers. Square Boxes are CONTROL Proportioning Reactors.

ON YOUR BOBBIN, RESET, GO!

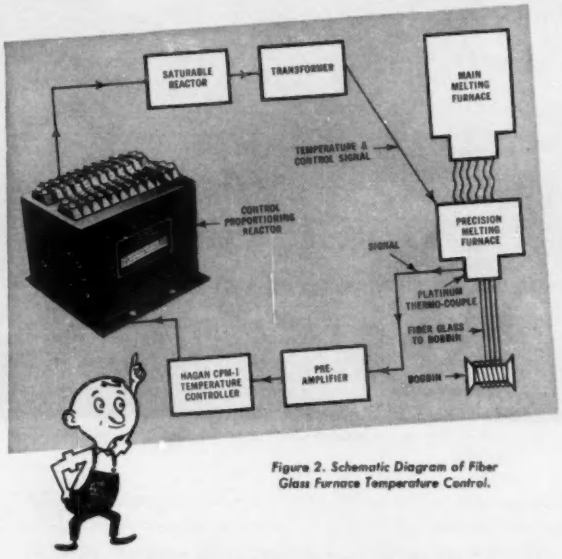

Figure 2. Schematic Diagram of Fiber Glass Furnace Temperature Control.

Fiber glass is pulled through a die in the bottom of a "bath tub" of molten glass at more than 3 miles per minute. It is wound on a bobbin, and when a "package" is completed, the operator has 15 seconds to change bobbins and restart the operation. There is as much as a 15° temperature upset in the system, yet when the winder restarts, the controller must reset the temperature at 2200° within ±¼° in the allotted 15 seconds. The CONTROL reactor puts out 100 watts at 80 volts, sufficient power to drive the saturable reactor ahead of it, and is at the instant beck and call of rapid and minute changes in signal. The response of the overall Hagan system is better than 0.1 seconds at full output. *When the first tests were run, accuracy of control was found to be even better than the ±¼° anticipated. Should you wish to learn more about these satisfactions with static control via our proportioning reactors, we'll be happy to answer your request for intimate details.*

STATIC CONTROL: (flexible and standard)

The function CONTROL Proportioning Reactors play in a system (the Hagan Temperature Controller is a telling example) is unique. The designer—for process control, for machine tool control, for assembly line control, for almost any control—can feed a variety of input signals into several isolated control windings in each proportioning reactor, and sum them to provide an amplified control signal. The reactor's figure of merit (ratio of volt-ampere amplification to time of response) is exceptional. It is as high as 1,500 for an N_C^2/R_C of 1,800. Thus, there is both power and sensitivity for the designer who works with static control. *Want to know who else among the nation's leaders have joined production-smart Pittsburgh Plate Glass in the swing to static control? We'll be happy to tell you—and to help with your static control ideas.*

Reliability begins with CONTROL

A DIVISION OF MAGNETICS INC.

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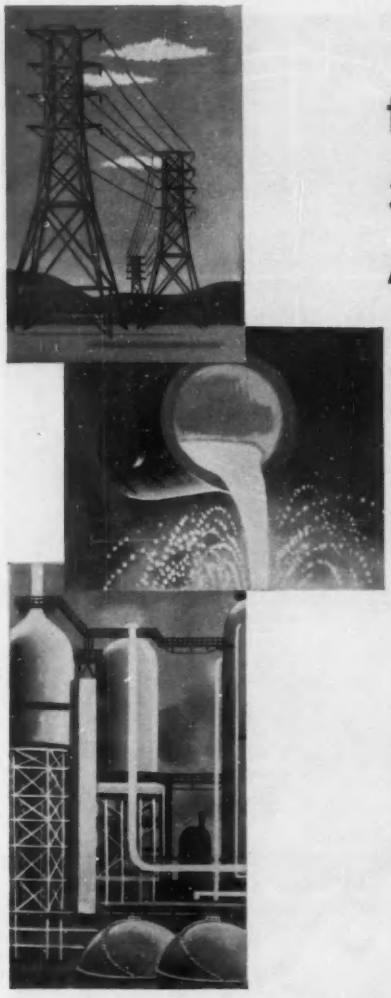
RCA-110 Industrial Control Computer
RCA-130 Industrial Data Transmission Link
RCA-150 Industrial Data Analyzer and Recorder



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3 NEW Electronic Systems that Advance Industrial Automation

... with capabilities that range from simple automatic monitoring and recording to complete real-time computer control of a complex "automated" operation over a wide geographical area.

Specifically designed for industrial applications and environment, the **RCA-110 Industrial Control Computer System** provides around-the-clock operating reliability, highest arithmetic speed and lowest cost installation. One megacycle, solid state circuits are conservatively operated. Optional sizes of random access core memories for working storage are combined with magnetic drums for bulk storage to provide greatest speed and desired memory size at reasonable cost. All options program-compatible with each. Easily expansible in field. Automatic priority program interrupt increases operating efficiency, permits continuous automatic self checking and enhances programming ease. Accepts binary or decimal data. 24 bit word length. One or two address. Seven index registers. Seventy-one instructions. Addition time, including access—56 microseconds. Strong, dust-tight, industrial housings are internally air conditioned. Slide-out chassis and built-in maintenance control panel permits fast front-of-cabinet maintenance.

RCA-130 Industrial Data Transmission Link removes the limitation of distance in an automatic monitoring or control system. Provides reliable on-line, real-time, telemetering, alarming and remote control signal transmission of analog or digital information via wire or radio, one-way or two-way. 100% parity check of digital information. 100% continuity check of communications circuit. Frequency shift tone keying. Frequency multiplexing or time sharing of channel as desired. Remote reports may be self-initiating or centrally sequenced. Low power requirements. Application engineered from standardized modules to completely fulfill specific requirements at minimum expense. Operates with RCA-110, RCA-150, or custom display and supervisory operating console.

High-speed, automatic monitoring and analysis of process and production status is provided by the **RCA-150 Industrial Data Analysis and Recording System**—plus computational capability for summarizing, averaging, totalizing and linearizing. Automatic alarms of process malfunctions. Accepts up to hundreds of inputs at a rate up to 1,000 points per second, with programmed or sequential scanning. Provides outputs for display panel, punched paper tape and typewriter, with provision for automatic standby. Display log format and speed to purchaser's specification. Internal, analog-to-digital conversion. All solid state circuitry, packaged for industrial environment, with optional internal air conditioning.

For special industrial control problems, **Custom Systems** can be supplied to fit your exact needs.

RCA Industrial Monitoring and Control Systems are available with Foxboro instrumentation.

For detailed information on the capabilities of RCA advanced Industrial Control Systems, consult your nearest Foxboro representative, or write—Industrial Computer Systems Department, Electronic Data Processing Division, Radio Corporation of America, 21 Strathmore Road, Natick, Massachusetts.

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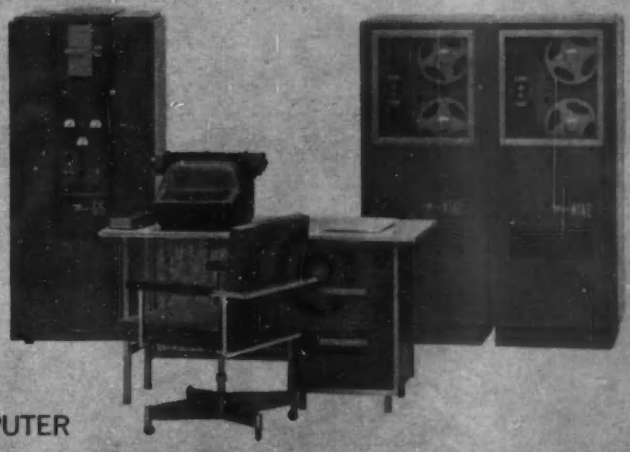


ALGO*

FOR THE BENDIX G-15 COMPUTER

Speeds and Simplifies Problem Solving

ALGO extends the problem-solving horizon of every engineer, focusing the speed and precision of the Bendix G-15 computer on any algebraically stated problem. ● A true mathematical equation solver, ALGO permits any engineer or scientist to program the computer in universal mathematical language. No previous knowledge of computers or programming is needed. Input/output, computation and data handling are all automatically controlled by the G-15 computer. ● Compare the number of steps in the ALGO program illustrated below with the number required to solve the same problem on a slide rule, desk calculator or any other computing system. You will see the time and cost-saving significance of this new Bendix G-15 automatic programming aid. ● Specifically designed to take advantage of the computing power and flexibility of the proven G-15, ALGO is the newest addition to an extensive library of Bendix automatic programming systems. See how the low-cost Bendix G-15 and ALGO combine to broaden application boundaries. Learn how this powerful team can save you valuable time . . . and greatly simplify problem solving.

* AN ALGEBRAIC COMPILER BASED ON INTERNATIONAL ALGOL.

PROBLEM: $$I = \frac{E}{\sqrt{R^2 + (6.2832\,FL - 1/6.2832\,FC)^2}}$$

(For values of R F & L as specified. For values of E ranging from 100 to 300 in increments of 50. For values of C ranging from .00002 to .000021 in increments of .0000001)

COMPLETE ALGO PROGRAM:

```
BEGIN ⑤
R = 10 ⑤
F = 60 ⑤
L = ₀2 ⑤
FOR E = 100(50)300 BEGIN ⑤
FOR C = ₀00002(₀0000001)₀000021 BEGIN ⑤
I = E/SQRT(R ↑ 2 + (6₀2832 * F * L — (1/(6₀2832 * F * C))) ↑ 2) ⑤
PRINT (FL) = E ⑤
PRINT (FL) = C ⑤
PRINT (FL) = I ⑤
```

Write on your letterhead for the self-teaching ALGO manual.

Bendix Computer Division
DEPT. W-23 LOS ANGELES 45, CALIF.

THE Bendix CORPORATION

TubeXperience in action

SUPERIOR—vast storehouse of "tubeXperience" for producers of measuring, indicating, recording and control devices

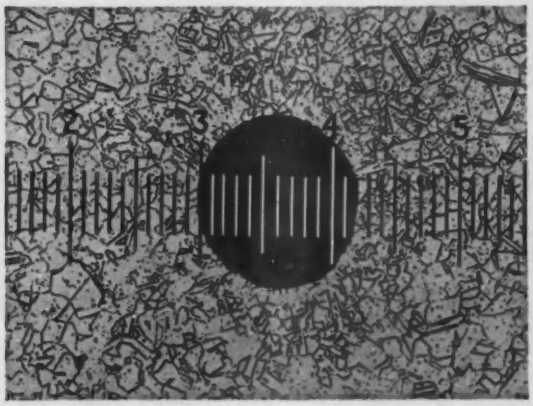
With a broad background of experience in producing small-diameter metal tubing to extremely close tolerances, Superior offers instrument makers a wide variety of materials, metallurgical competence, and manufacturing skills that save trial and error in the design stage, besides time and cost in production.

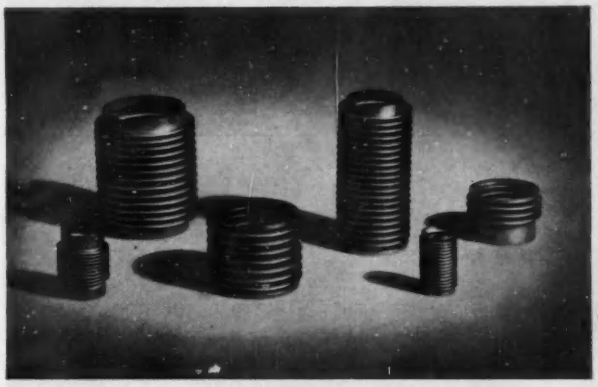
Supplied in over 120 analyses, Superior Tubing is used in virtually every type of measuring, indicating, recording and control device. Wherever it is used, the chances are that some special property required for the application was met from Superior's vast storehouse of "tubeXperience."

Bulletin 380, "Specialty Tubing for Industrial Instrumentation," gives application data, required characteristics, materials usually specified, range of sizes, tolerances, and other pertinent information on the many types of specialty tubing produced by Superior for the instrument maker. Send for your copy today. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

Capillary ID size checked under 100x magnification

—yet this critical inspection is only 1 of 3 used to prove ID of Superior capillary tubing. In checking the ID size of capillary tubing we don't rely on only one reading from our inspection microscope, we require four. Then we double-check in two other ways—with a relatively simple plug gage; and a comprehensive flow inspection to ascertain the average ID.



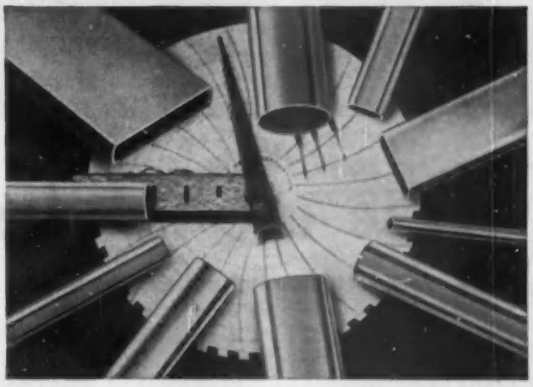


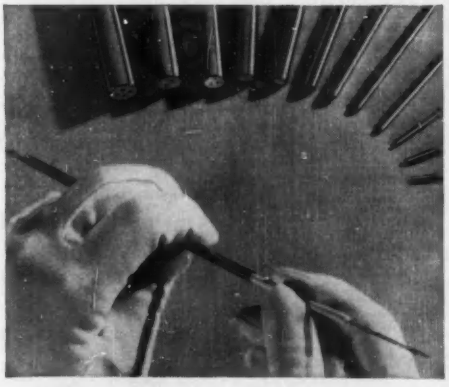
750,000 flexures without failure

—but not an unusual record for bellows formed from Superior thin-wall tubing. Thin-wall tubing of bellows quality—usually under .010 in. max. wall thickness and held to a tolerance spread of only one-thousandth inch—requires the skills and facilities of specialists. It must be extremely ductile—forming pressures can run as high as 5000 psi; brazing can subject it to temperatures up to 1800°F; it must be free of carburization, dents and pickups. We maintain the necessary production standards, employ unique handling procedures, use special controlled-atmosphere furnaces.

Rx for accurate indication of pressure and temperature

—Bourdon tubing by Superior. The tubing from which Bourdon elements are made must be free of carburization or decarburization, rough or corroded surfaces, and variations in wall thickness. It must have good corrosion and drift resistance, also low hysteresis. It must have the extra qualities that permit fabrication of Bourdon elements that are interchangeable in the field with maximum ease, and with only linkage adjustment.





For protection of the equipment and processes it serves

—tubing for thermocouple sheathing must be clean. Tubing with an unusually clean, smooth ID and produced to extremely close tolerances is a prime requisite for sheathing ceramic-pack thermocouples. Also it must be adaptable to temperature extremes (—300 to +2100°F), have high scaling resistance and resistance to shock, fatigue and corrosion. To assure ID cleanliness, Superior recently established a new specification covering this important requirement.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to 5/8 in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

These are no sissies!

They are AE Hydramite® pumps, the heavy-duty hydraulic pumps that start delivering where other "heavy-duty" pumps leave off. Check into them for the tough jobs where you want sheer stamina...the jobs where extra reliability and sustained performance are an urgent requirement.

To meet your specific requirements, Hydramite pumps can be supplied for constant displacement from 3 to 25 gpm at 5,000 psi and 60 to 100 gpm at 3,000 psi for hydraulic fluids with viscosities of 150 to 300 ssu at 100°F. In special applications they have handled viscosities as low as 40 and as high as 900 ssu at 100°F. Special materials and seals permit handling of missile fuels and special fluids at higher temperatures. Available in flange, foot or face mounted styles.

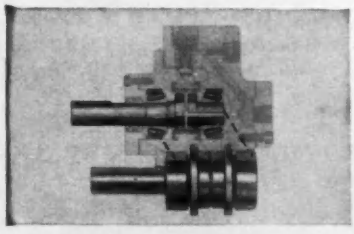
Write or call American Engineering Company, Dept. P-153, Philadelphia 37, Pa. Phone: CUmberland 9-3800.

See our four-page catalog in Sweet's Product Design File, or write us for reprint (Catalog P-60).

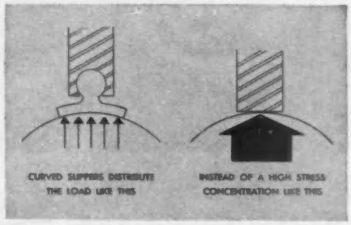
AMERICAN ENGINEERING COMPANY

Division of United Industrial Corporation

Hele-Shaw® Pumps, Lo-Hed Hoists, AE Marine Deck Auxiliaries, Vibra-Grate, Perfect Spread and Taylor Stokers.



Tapered roller bearings. High-capacity, heavy-duty tapered roller bearings support the eccentric cam shaft. This means that a Hydramite can take more punishment . . . handle heavier unbalanced loads . . . and last longer.



Curved Slipper distributes thrust load of the plungers and reduces unit stress to the point where maintenance is never required at what is a critical wear spot in most hydraulic pumps.

CONVECTION COOLED GUARANTEED 5 YEARS

LAMBDA Transistorized Power Supplies

LA Series

5 and 10 AMP • 0-34 VDC

3½" Panel Height on 5 AMP Models

CONDENSED DATA ON LA SERIES

LA 50-03AM	(with meters)	0-34 VDC, 0-5A	$425.
LA 100-03AM	(with meters)	0-34 VDC, 0-10A	540.
LA 50-03A	(without meters)	0-34 VDC, 0-5A	395.
LA 100-03A	(without meters)	0-34 VDC, 0-10A	510.

MODEL	VOLTAGE STEPS
LA 50-03A, LA 50-03AM	–2, 4, 8, 16 and 0-4 volt vernier
LA100-03A, LA100-03AM	–2, 4, 8, 16 and 0-4 volt vernier

Regulation: *Line* Better than 0.15 per cent or 20 millivolts (whichever is greater). For input variations from 100-130 VAC. *Load* Better than 0.15 per cent or 20 millivolts (whichever is greater). For load variations from 0 to full load.

AC Input: 100-130 VAC, 60 ± 0.3 cycle. This frequency band amply covers standard commercial power lines in the United States and Canada.

Ripple and Noise: Less than 1 millivolt rms.

Ambient Temperature: 50°C—continuous duty.

Remote DC Vernier: Provision for remote operation of DC Vernier.

Remote Sensing: Provision is made for remote sensing to minimize effect of power output leads on DC regulation, output impedance and transient response.

Size:

LA 50-03A	3½" H x 19" W x 14⅜" D
LA 100-03A	7" H x 19" W x 14⅜" D

LT Series

1 and 2 AMP • 0-32 VDC

Compact 3½" Panel Height

CONDENSED DATA ON LT SERIES

LT 1095M	(with meters)	0-32 VDC, 0-1 AMP	$315.
LT 2095M	(with meters)	0-32 VDC, 0-2 AMP	395.
LT 1095	(without meters)	0-32 VDC, 0-1 AMP	285.
LT 2095	(without meters)	0-32 VDC, 0-2 AMP	365.

MODEL	VOLTAGE BANDS
LT 1095, LT-1095M	0-8, 8-16, 16-24, 24-32
LT 2095, LT-2095M	0-8, 8-16, 16-24, 24-32

Regulation: *Line* Better than 0.15 per cent or 20 millivolts (whichever is greater). For input variations from 105-125 VAC. *Load* Better than 0.15 per cent or 20 millivolts (whichever is greater). For load variations from 0 to full load.

AC Input: 105-125 VAC, 50-400 CPS.

Ripple and Noise: Less than 1 millivolt rms.

Ambient Temperature: 50°C—continuous duty.

Remote DC Vernier: Provision for remote operation of DC Vernier.

Remote Sensing: Provision is made for remote sensing to minimize effect of power output leads on DC regulation, output impedance and transient response.

Size:

LT 1095	3½" H x 19" W x 14⅜" D
LT 2095	3½" H x 19" W x 14⅜" D

SEND TODAY FOR COMPLETE DATA.

LAMBDA ELECTRONICS CORP.

11-11 131 STREET • DEPT. 4 • COLLEGE POINT 56, N. Y. • INDEPENDENCE 1-8500

LA110

CIRCLE 85 ON READER SERVICE CARD

When crews of SAC's 1st Missile Division successfully launched the USAF ICBM Atlas from Vandenberg Air Force Base, September 9, 1959, the world became aware that the United States had brought into being a formidable retaliatory power for peace. Within four months after the first operational launch, the Air Force doubly underlined this missile's capability. On a single day, January 26, 1960, the 16th and 17th consecutive successful Atlases were fired intercontinental ranges to predetermined targets from both Atlantic and Pacific bases.

After only five years of intensive development, including concurrent research, testing and fabrication under this nation's top military priority, Atlas is extremely versatile as well as powerful. It was the Project Score satellite vehicle and is scheduled for use in Project Mercury, the Man in Space Program, and in other space exploration missions. Thus, used as a booster for space projects, Atlas provides the nation with a key capability in scientific as well as military applications.

Space Technology Laboratories provides the systems engineering and technical direction for the Atlas as well as other portions of the Air Force Ballistic Missile Program. Much of what was learned in building Atlas has helped cut the lead-time in the development of such other Air Force Ballistic Missiles as Thor, Titan and Minuteman.

Among the industrial organizations which have worked in concert in developing Atlas are such major contractors as: Convair, Division of General Dynamics Corp. for airframe, assembly and test; General Electric Co. and Burroughs Corp. for radio guidance; Arma, Division of American Bosch and Arma Corp. for inertial guidance; Rocketdyne Division of North American Aviation, Inc., for propulsion; General Electric Co. for re-entry vehicle; Acoustica Associates for propellant utilization.

America's first intercontinental ballistic missile...is helping to bear the burden of today's power for peace

ATLAS

The continuing development of Atlas as well as other USAF missiles and related space probes, has created important positions on STL's technical staff for scientists and engineers with outstanding capabilities in: thermodynamics, aerodynamics, electronics, propulsion systems, structures, physics, computer technology, telemetry, and instrumentation. If you believe you can contribute in these or related fields and disciplines, you are invited to send your resume to:

SPACE TECHNOLOGY LABORATORIES, INC.

P. O. Box 95004, Los Angeles 45, California, Attention: Richard A. Holliday

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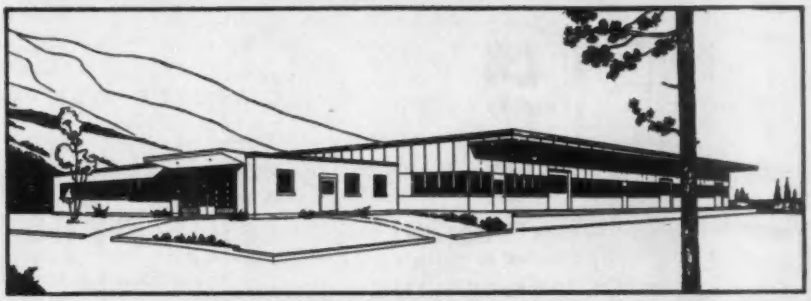
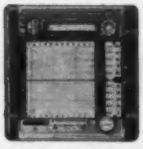




NEW HOME FOR SWARTWOUT AUTRONIC® CONTROLS. INDUSTRY'S FIRST AND "OLDEST" FULLY ELECTRONIC CONTROL SYSTEMS NOW COME TO YOU FROM THE NEWEST INSTRUMENT PLANT IN THE COUNTRY. Expanded facilities. Improved manufacturing techniques. Computer-automated production and inventory control. These and other recently instituted efficiencies have pushed Autronic production to record levels in record time. Our field engineering staff has been enlarged, too. Service is better all the way around. Now, more than ever before, Swartwout is the leader in electronic process instrumentation.

SWARTWOUT

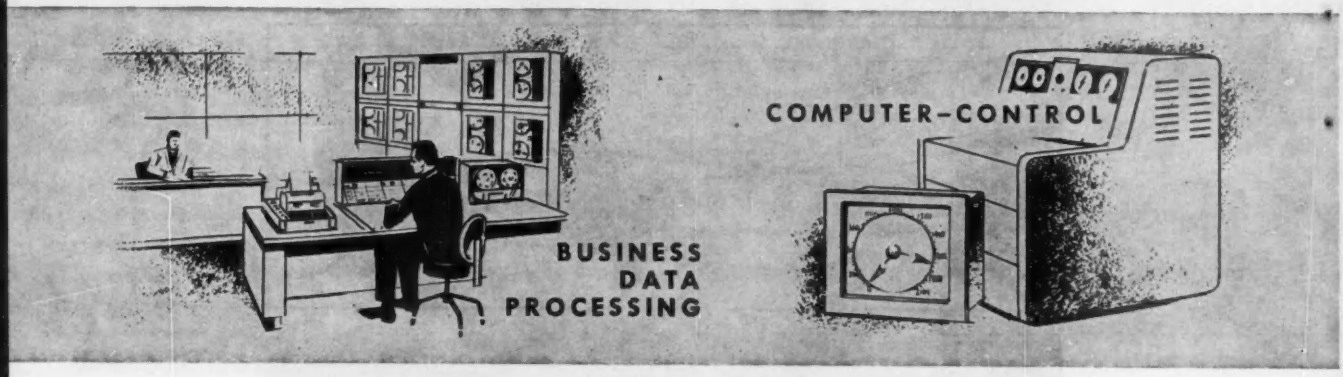
SWARTWOUT DIVISION, CRANE CO.

Hocksett Industrial Park, Manchester, New Hampshire

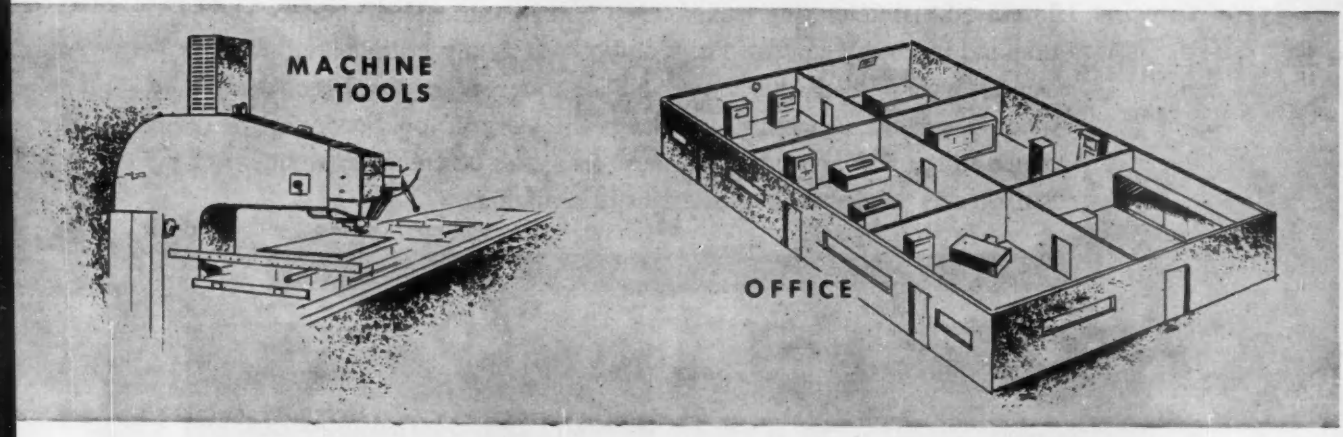
CRANE

AUTOMATION SYSTEMS

PLANNING TOGETHER WITH GENERAL

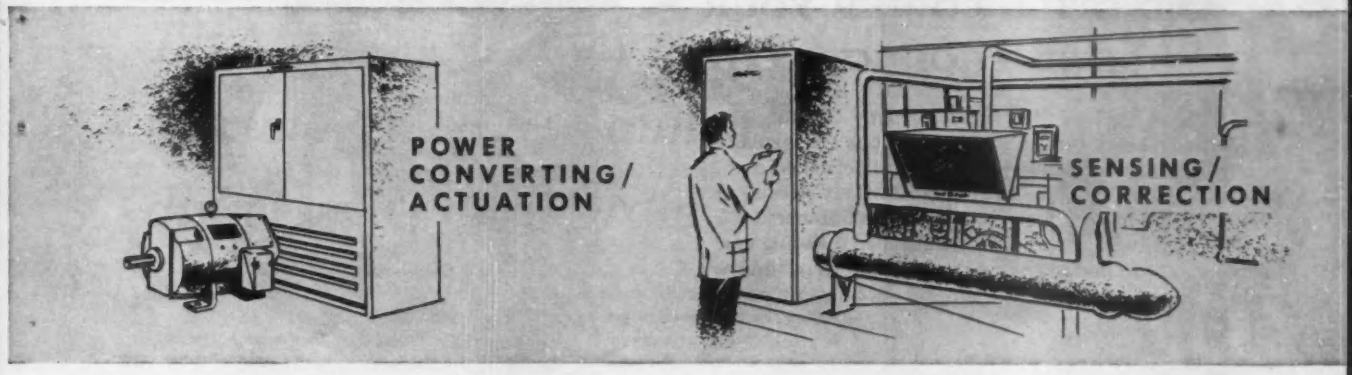


AND EQUIPMENT FOR NEEDED APPLICATIONS

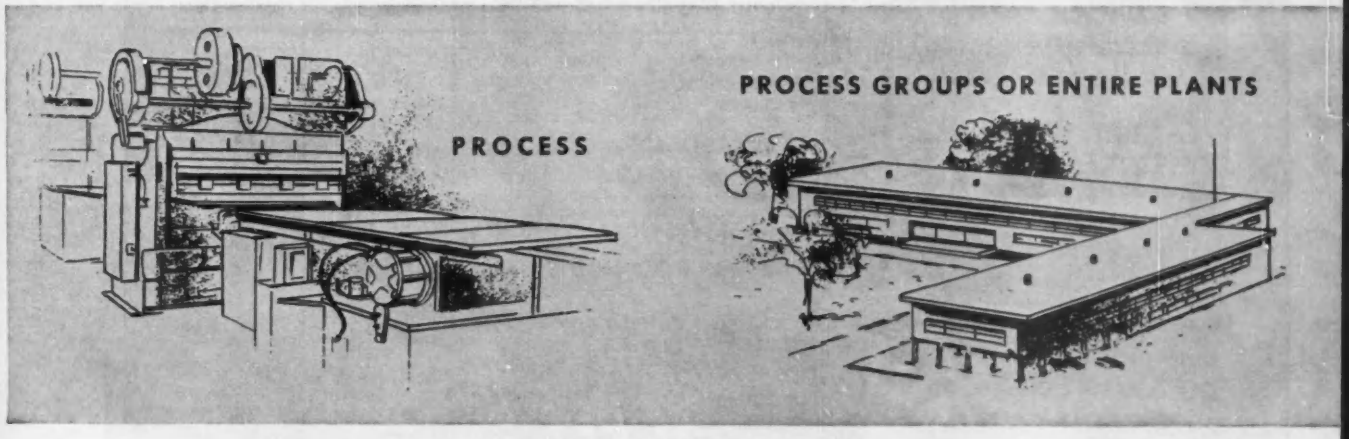


...OPTIMUM AUTOMATION BENEFITS

ELECTRIC FOR A PERFECT BALANCE OF MEN . . .



ASSURES GREATER OPERATING PROFITS FOR . . .



General Electric's resources of knowledge and system experience are available to help all industries realize their greatest automation potential. With the most complete line of equipment designed for automation, General Electric can help you with a step-by-step implementation program leading to an integrated system, designed to yield maximum profits. For more specific information, visit with General Electric at one of the following shows or contact your nearest G-E Apparatus Sales Office. *General Electric Company, Schenectady 5, New York.*

SJ-538

Machine Tool Exposition—Production Engineering Show Booths 110, 112, and 114 Chicago's Navy Pier Sept. 6-16.

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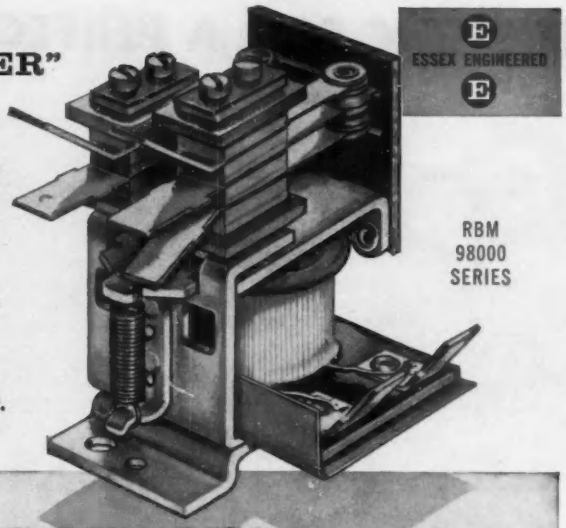
Progress Is Our Most Important Product

GENERAL ELECTRIC

CIRCLE 89 ON READER SERVICE CARD

SMASH THE "DESIGN BARRIER" AND STILL LOWER YOUR FINISHED PRODUCT COST!

Since the basic relay and its many contact forms, ratings, and terminal variations are regular production items at RBM, design bottlenecks can be shattered. RBM has "CUSTOMERIZED" these relays to fulfill almost every conceivable requirement. This vast background of application engineering can serve you with design shortcuts . . . lower your "finished product" cost. Ask your RBM product application engineer.



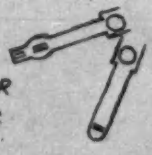
RBM 98000 SERIES

CHECK THE FEATURES OF THIS RBM AC OR DC GENERAL PURPOSE RELAY

MANY ARE LISTED BY U/L FILE NOS. E12139 OR E22381

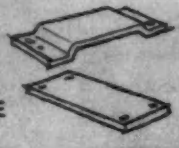
PRESSFIT PILE-UP ELIMINATES DRIFT; ASSURES CONTACT STABILITY

DEPENDABLE CROSS-BAR CONTACTS AVAILABLE FOR LOW VOLTAGE AND/OR LOW CURRENT CIRCUITS



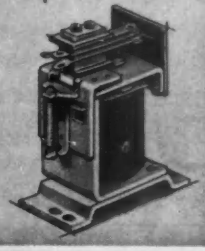
SIMPLIFIED MAGNET FRAME AND ARMATURE ASSEMBLY PROVIDES EFFICIENT, POSITIVE ACTION

VARIETY OF MOUNTINGS AVAILABLE



OTHER FEATURES	A.C. 98700 TYPE	D.C. 98600 TYPE
• MAX. COIL VOLTAGE	230AC	115 DC
• MAX. COIL RES. IN OHMS	—	20000
• MAX. COIL WATTS OR VOLT AMPS.	9.0 V.A. INRUSH 6.5 V.A. SEALED	4.0 W.
• MAX. CONTACT FORM WITH RATED CURRENT AT 32 V. DC OR 115 V. AC (NON-INDUCTIVE LOAD)	2PDT 15 AMPS. 4PDT 6 AMPS. 6PDT 3 AMPS.	2PDT 15AMPS. 4PDT 6AMPS. 6PDT 3AMPS.
• APPROX. WEIGHT	4.1 OZ.	4.1 OZ.

ALSO AVAILABLE IN 97000 SERIES PROVIDING ADDITIONAL COIL POWER... GREATER SENSITIVITY



Consult Your Local RBM Product Application Engineer or Write For Bulletin 1060

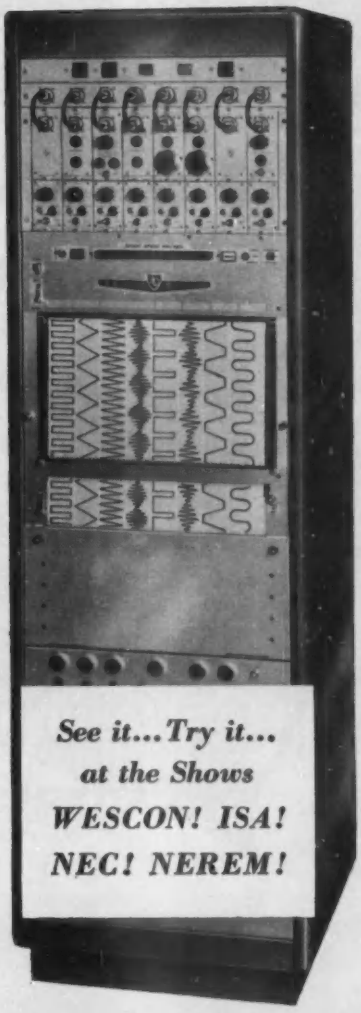
RBM Controls Division

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA

Factories Located at North Manchester and Logansport, Indiana

Here's why the NEW AO TRACE-MASTER is the world's finest 8-channel direct writing recorder!

American Optical Company, famous for precision instrumentation for 138 years, introduces an electronic direct-writing recorder of unique design, in which ultra-precise electromechanics has been combined with advanced electronics to achieve *truly superior performance.*



Finest Writing Method Ever

Unique direct-carbon-transfer writing method. Trace is uniformly black and up to four times thinner than that made by any other recorder. Minute variations in phenomena measured are more faithful, meaningful. Carbon trace cannot fade... may be easily reproduced.

Finest Frequency-Amplitude Performance

TRACE-MASTER'S multiple-feedback wide-range Driver circuitry, combined with the advanced pen-motor design, produces wider frequency response *at larger amplitudes* than any other recorder. TRACE-MASTER response is flat—*within 1%*—from dc to 110 cps at 40 mm!

Band Amplitude Product (i.e. Bandwidth times Amplitude) is 5600...140 cps (3 db point) x 40mm!

Finest Chart-Drive Facilities

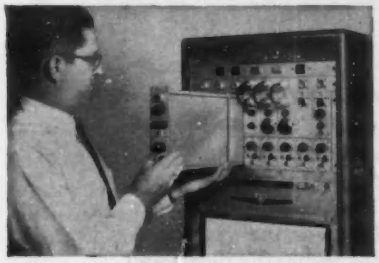
TRACE-MASTER provides widest chart-speed range...0.1 to 500 mm/sec...of any direct-writing recorder! Convenient push-button selection. Take-up reel automatically stores full 1000 ft. record. Writing table tilts for easy chart annotations. Guide rails permit quick, easy paper-roll changes. Low cost chart paper makes practical protracted recording at high speeds.

Finest Resolution, Linearity, Stability

Thin carbon trace (thinner by 4 to 1 over most recorders) and high Band Amplitude Product (higher by 6 to 1 over other recorders) provide up to 24 times the resolving power or ability to detect short, sharp variations in the record. The superior linearity (± 1%) and stability in rectilinear presentation permit full use of this unexcelled resolution.

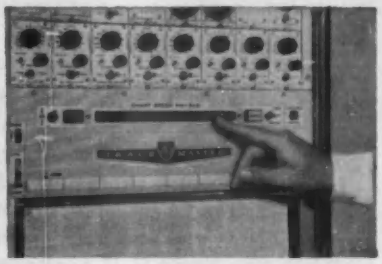
Finest Systems Oriented Compatability

Fully transistorized circuitry...application of combined dc level and signal multiple feedback...complete interchangeability of modular signal-conditioning elements... are some of the features that make the AO TRACE-MASTER the world's finest 8-channel direct writing recorder.



Entire channel easily accessible and completely interchangeable as single unit.

Platen tilts to convenient writing angle.



Widest range chart speed . . . push-button selection through 0.1 mm/sec to 500 mm/sec.

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Complete Engineering Bulletins available. Field Sales Engineers at your service everywhere.

American Optical
COMPANY

INSTRUMENT DIVISION, BUFFALO 15, NEW YORK

Dept. J284

Please send Engineering Bulletins on the complete AO TRACE-MASTER line of recording modules and systems.

Name_____

Business Address_____

City_____ Zone____ State_____

New Random Access Memory Package...

uses only 18.75"
IN STANDARD 19" RACK

GENERAL CERAMICS, continuing its leadership in the memory packaging field, has made available double and triple bay random access memories with up to 4096 characters x 32 bits per character at cycle times up to 6 micro-seconds. Now you can get design economy since the basic G-C package requires only 18.75" of standard rack space—a reduction of up to 80% over typical units requiring a full six feet.

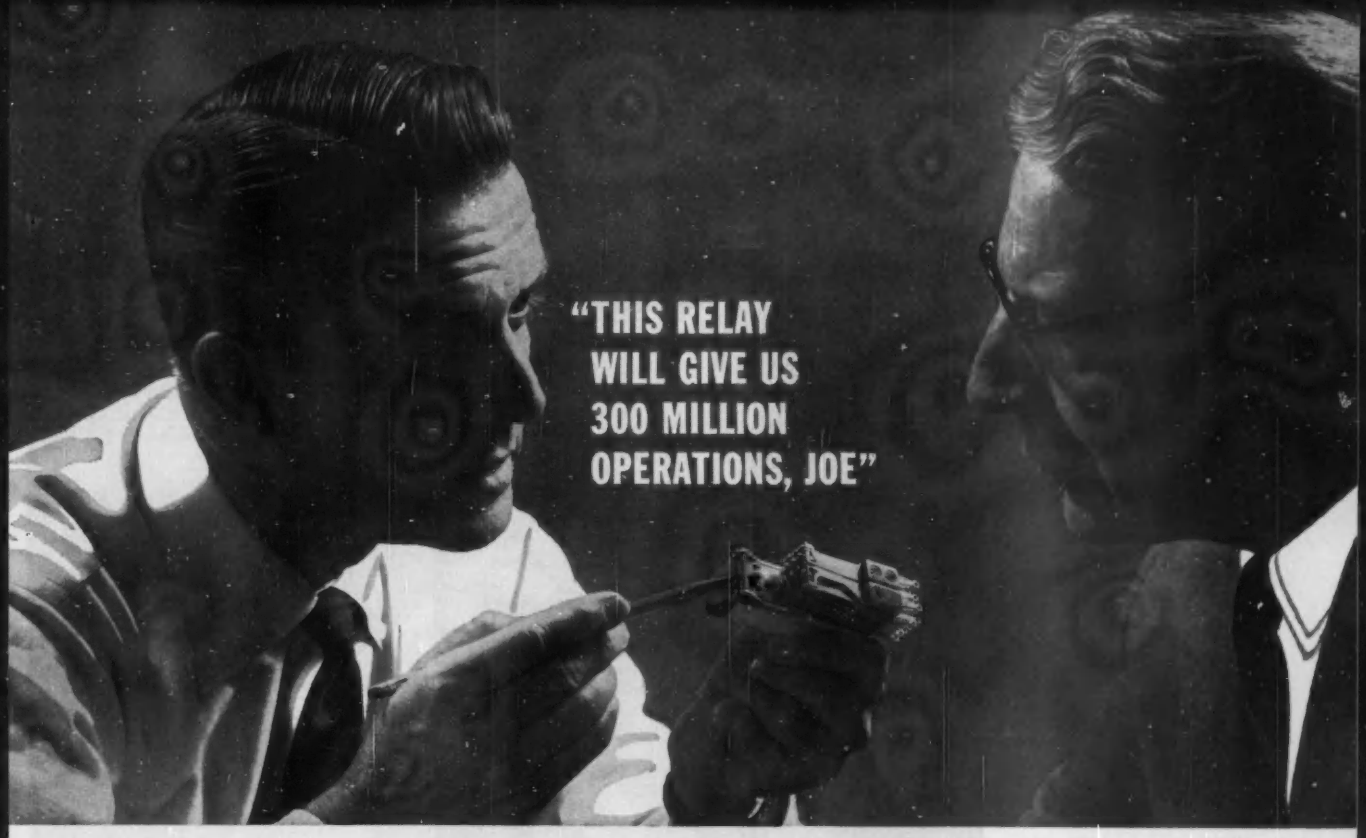
General Ceramics offers space-saving random access memory designs with varying number of characters, word lengths and logic.

Optional design features include parity checking, test cycles, indicator lights and power supply locations.

Write on your company letterhead for additional information.
Please mention your requirements; address inquiries to Section CE.

DIVISION OF INDIANA GENERAL CORPORATION

APPLIED LOGIC DEPARTMENT
GENERAL CERAMICS
KEASBEY, NEW JERSEY, U.S.A.
TECHNICAL CERAMICS, FERRITE AND MEMORY PRODUCTS



HERE'S WHY P&B TELEPHONE TYPE RELAYS GIVE YOU

reliable performance over long life

Armature Pin Bearing shows only .0005" increase in clearance after 300 million operations.
Heavy Duty Frame maintains dimensional stability, adds to relay's sensitivity.
Husky Armature Arm prevents sagging or bending.

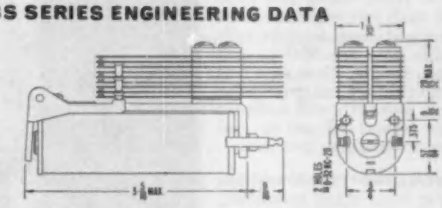
BS SERIES TELEPHONE TYPE

Measure the thickness of the BS series armature arm. You will find the cross section area is greater than ordinary relays of this type. Here is the kind of quality that spells dependability.

Observe that the stainless steel hinge pin runs the full width (not just half) of the armature, providing optimum bearing surface. This pin, operating in a stainless steel sleeve, shows only minimal wear during nearly a *third of a billion operations.*

Best of all, P&B quality costs no more. A whole new plant is being devoted to the production of high performance telephone type relays. Your nearest P&B sales engineer will be happy to discuss your relay problems. Call him today.

BS SERIES ENGINEERING DATA



GENERAL:
- **Breakdown Voltage:** 1000 volts rms 60 cy. min. between all elements.
- **Ambient Temperature:** −55° to +85° C. +125° C available on special order.
- **Weight:** 9 to 16 ozs.
- **Terminals:** Pierced solder lugs; Coil: One #16 AWG wire Contacts: Two #18 AWG wires
- **Enclosures:** Dust covered or sealed

CONTACTS:
- **Arrangements:** DC—up to 28 springs AC—up to 24 springs
- **Material:** ⅛" dia. twin palladium. Up to ¼" dia. single silver. Other materials on special order.
- **Load:** 4 amps at 115 volts, 60 cycle resistive
- **Pressure:** 15 grams minimum

COILS:
- **Resistance:** 100,000 ohms maximum
- **Current:** 10 amps maximum
- **Power:** DC—50 Milliwatts per movable arm. Greater sensitivity on special order. AC—17.9 volt-amps.
- **Duty:** Continuous
- **Treatment:** Centrifugal impregnation
- **Voltages:** DC—up to 300 volts with series resistor. AC—up to 250 volts, 60 cy.

MOUNTING: Two #8-32 tapped holes ¾" o.c. Other mountings on special order.

GS SERIES—Excellent sensitivity: 50 mw per movable arm minimum (DC). For applications requiring many switching elements in small space.

LS SERIES—Medium coil relay with short springs and light weight armature for fast action, reliability and long life.

TS SERIES—Short coil relay is available in AC and DC versions. Long life construction. Can be supplied (DC) with up to 20 springs (10 per stack).

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC PARTS DISTRIBUTOR

POTTER & BRUMFIELD

DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY, PRINCETON, INDIANA

IN CANADA: POTTER & BRUMFIELD CANADA LTD., GUELPH, ONTARIO

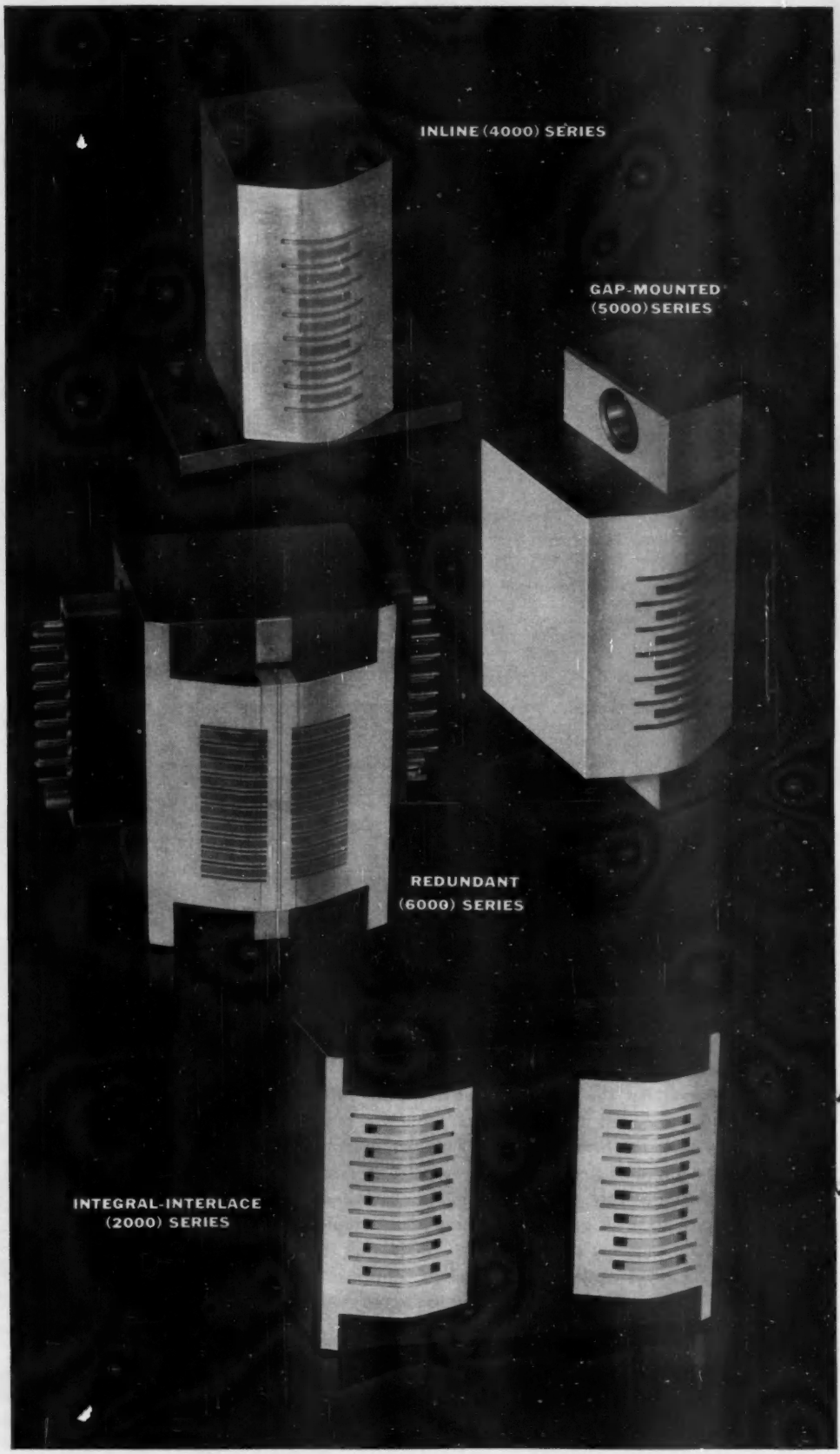
CIRCLE 93 ON READER SERVICE CARD

INTEGRAL-INTERLACE (2000) SERIES: Two inline head stacks (with interlaced channels) mounted on integral "H" block record more channels per inch of tape width, while maintaining high output per channel and strong shielding against channel crosstalk. Patented "gap-mounted" feature ensures accurate location of each stack. IRIG telemetering standard available (exclusive design maintains IRIG time relationship despite normal head wear). Identical (non-interlaced) stacks can be used in redundant analog applications.

INLINE (4000) SERIES: Records or reproduces simultaneously on many channels of a single tape or drum. Precise perpendicularity and colinearity of gaps and accurate track width and location with reference to other tracks and base assures reliable data transfer to and from media. Base and full metal-face machined for correct azimuth and contact angle (standard and special base mountings available).

GAP-MOUNTED® (5000) SERIES: Unique head stack mounting permits quick interchangeability without critical adjustment of head azimuth, contact angle or gap perpendicularity. Adjoining faces of head and mounting structure are lapped with reference to the gap line. Mounting structure is adjusted permanently and four set screws hold head in precise location.

REDUNDANT (6000) SERIES: Two identical head stacks are mounted opposite each other in a single structure, with closely spaced gap lines (down to .150 inch). Digital data recorded by first stack is read for reliability check by the second stack. Close spacing between gaps reduces storage capacity required in checking register.



SIMPLIFY RELIABLE RECORDING SYSTEM DESIGN WITH...

CLEVITE

"optional characteristic" magnetic heads

An analysis of present usage and future trends in magnetic recording heads, transports, media, and associated electronics indicates areas for partial standardization of these interdependent components. Within the framework of these partial standards, Clevite offers "optional characteristic" magnetic heads to simplify the design of reliable analog and digital recording systems.

These new designs provide a choice of electrical characteristics. Four basic mechanical configurations are available in six compatible tape formats with track widths from .020 inch to .050 inch, and spacings of .050 inch to .140 inch. These provide from 7 to 20 inline channels per inch.

Detailed mechanical drawings and specifications plus actual electrical performance data are available *before the fact*. This allows the design engineer to predict reliably the overall recording system performance.

Clevite continually produces beneficial design improvements in such areas as high resolution and flux-responsive readout, and high-efficiency record structures. As these developments are field-proved they are adopted in Clevite "optional characteristic" designs. These dynamic standards thus offer recording system designers magnetic heads that include up-to-date advances in recording technology.

Write today for Bulletin 9398 on Clevite "Optional Characteristic Magnetic Heads".

CLEVITE ELECTRONIC COMPONENTS

DIVISION OF

3405 Perkins Avenue — CLEVITE CORPORATION — Cleveland 14, Ohio

Field Sales Engineering Offices:

60 Franklin Street, E. Orange, New Jersey
1915 N. Harlem Avenue, Chicago, Illinois
3402 W. Century Blvd., Inglewood 2, California

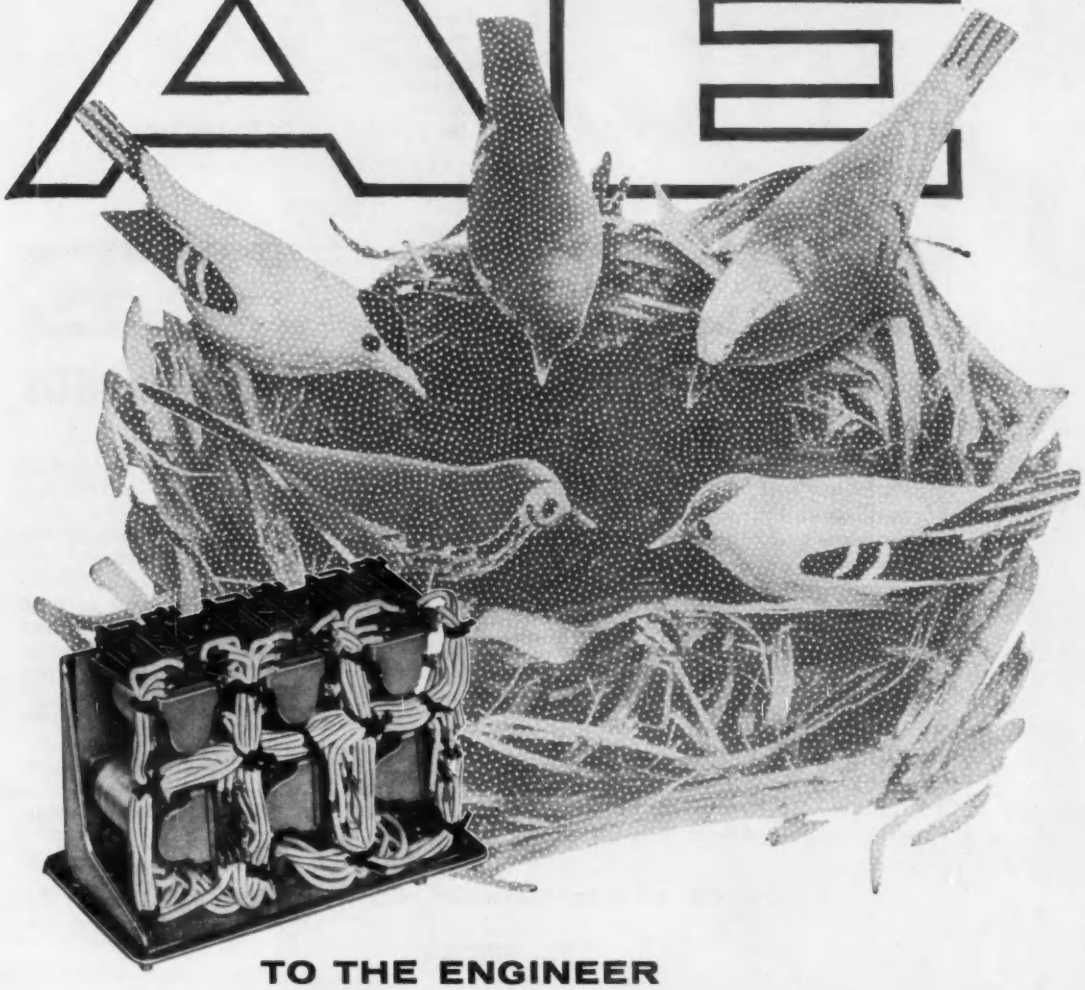
ELECTRICAL CHARACTERISTICS

	Designation	Description	Inductance (maximum)	Gap Length	Bias Current*	Record Current**
ANALOG	ARL	Low impedance record head. Used with transistor driver.	1.30 MH	.0005"	6 to 20 MA, up to 1 mc	0.7 MA 8db below saturation
ANALOG	ARH	High impedance record head. Used with vacuum tube driver.	10 MH	.0005"	2 to 4 MA, up to 500 kc	0.2 MA 8db below saturation
ANALOG	APH-ACH	High impedance playback head or combination record/playback head.	80 MH	.00025"	1 MA up to 60 kc	.09 MA
ANALOG	ACL	Low impedance combination record/playback head for use up to 100 kc at 60 ips with 400 kc bias, or to 200 kc at 120 ips with 1 mc bias on half winding.	15 MH	.00025"	2.5 MA	0.1 MA
DIGITAL	DRL	Low impedance record head. Used with transistor driver. 12 volts single ended, or 6 volts double ended.	4.5 MH	.0005"	——	9 MA peak
DIGITAL	DRH	High impedance record head. Used with vacuum tube driver. Used as playback with DRL head.	55 MH	.0005"	——	3.5 MA peak
DIGITAL	DRP	Redundant record playback head.	18 MH	.0005" each	——	4 MA peak

*Depending on bias frequency and channel spacing.
**Analog—6db below saturation for minimum distortion.
Digital—for 130% saturation at 200 flux changes per inch, 60 ips.

CIRCLE 95 ON READER SERVICE CARD 95

AE



TO THE ENGINEER

who thinks "birds' nests" are for the birds...

Upset over the fancy wiring your control package demands? Relax! AE can turn a bird's nest into a thing of beauty *and* high reliability.

The reason is simple: we've had years of experience wiring complex dial telephone switchboards, to say nothing of little black boxes. And we have the techniques down so tidy and pat that our assembly and prewiring costs are more than likely lower than yours.

As a beautiful example, take a look at the compact relay complex illustrated. This custom job is designed to do switching tricks over and over again without failure. A significant part of its dependability is structural rigidity.

AE engineers are also gifted in solving the most complex switching circuits in the simplest and most inexpensive way. Chances are they can save you some headaches.

If you have a control problem, we'd like to hear about it. Just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. And while you're at it, ask for Catalog 4083-A covering *AE Enclosures for Relays, Switches and Control Systems.*

AE CAN DO

AUTOMATIC ELECTRIC

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

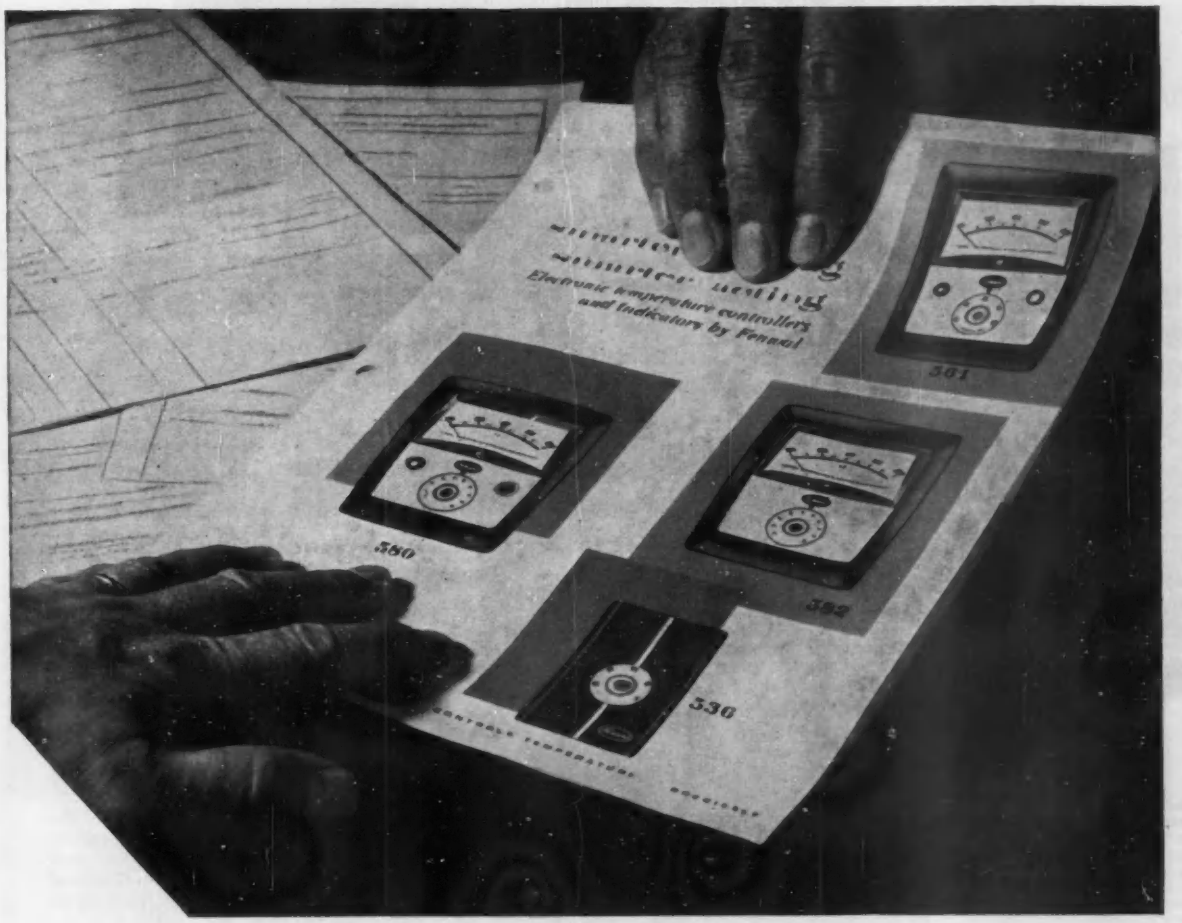
"Wait! I need it too!"

Everyone concerned with temperature control will want to read this new Fenwal Bulletin, "Smarter Looking — Smarter Acting Electronic Temperature Controllers and Indicators."

These modern transistorized instruments with thermistor sensors can be *more precisely matched* to requirements over a range from −50 to +600°F. Their many interchangeable, optional features let you order *exactly* what you need. And you can *combine* instruments . . . "build" to your specifications.

Here are just a few possibilities: single-point control . . . single-point control and indication . . . indication of up to ten controlled temperatures . . . ON-OFF or proportioning . . . indicating or non-indicating . . . set-point adjustment at instrument or remote . . . expanded scales for fine temperature adjustment . . . and many more. Ratings up to 10 amp/110 VAC. Each instrument is professionally styled to perfectly complement modern industrial machines or interiors. And, best of all, Fenwal design keeps costs *reasonable.*

Get your copy of "Smarter Looking — Smarter Acting." Then get the *benefits* of this versatile new instrument family. Write FENWAL INCORPORATED, 299 Pleasant Street, Ashland, Mass.



Another example of how Fenwal CONTROLS TEMPERATURE . . . PRECISELY

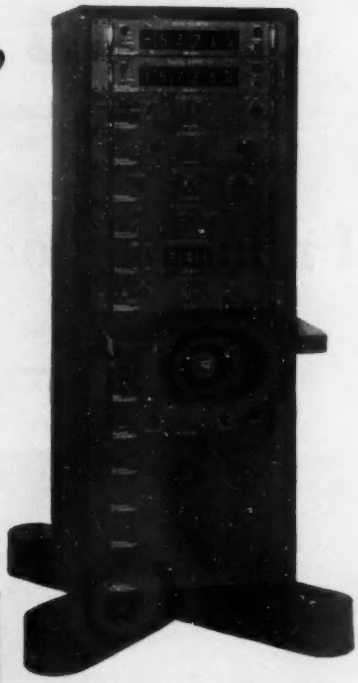
CIRCLE 97 ON READER SERVICE CARD

ELECTRO INSTRUMENTS can meet your systems needs NOW... with HARDWARE, NOT PROMISES!

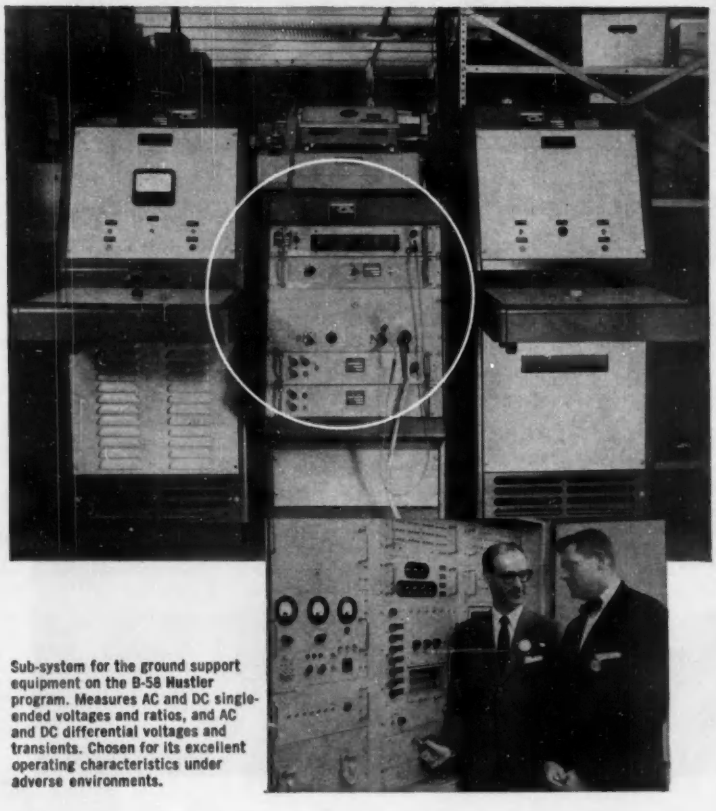
Systems shown here are typical of more than 200 designed and built by EI and now in use. They range in complexity from data logging systems for automatic scanning, measurement and recording of data from multiple transducers...to high speed, automatic checkout systems for missile and aircraft...to systems for automating industrial processes.

Because of the EI modular design approach, many of these systems can be delivered on virtually an off-the-shelf basis, eliminating the long delivery times usually associated with system development. This approach also results in a low cost system because the modules are manufactured in large quantities. Cost is almost a linear function of performance capabilities desired.

Why not talk over your digital system requirements with your EI Sales Engineer? His system experience will be a valuable help in solving your problem.



Multi-purpose digital system for measuring a variety of transistor parameters while the transistors are being subjected to environmental testing.



Digital read-out sub-system of a large, automatic, transistor production checkout system.

Sub-system for the ground support equipment on the B-58 Hustler program. Measures AC and DC single-ended voltages and ratios, and AC and DC differential voltages and transients. Chosen for its excellent operating characteristics under adverse environments.

you get MORE with EI systems!

MORE VERSATILITY—AC and DC voltages, AC and DC voltage ratios, ohmic resistances, capacitance, frequency, phase, inductance, time, or combinations of these basic input quantities can be accepted by the EI system.

MORE RELIABILITY—Maximum use is made of solid-state and MIL-type components which are designed into conservatively-rated, field-proven circuits. All vendor-supplied parts are exhaustively tested and evaluated.

MORE FLEXIBILITY—Expansion of the EI system can be made by simply adding appropriate new modules. This approach eliminates new engineering development costs each time needs change; minimizes system obsolescence.

Electro Instruments, Inc. EI 3540 AERO COURT SAN DIEGO 11, CALIF.

DIGITAL INSTRUMENTS FOR MEASURING AC/DC VOLTAGES, AC/DC RATIOS, RESISTANCE, CAPACITANCE, AND FREQUENCY • X-Y RECORDERS & ACCESSORIES • DC AMPLIFIERS

4 ROTARY SELECTOR SWITCHES

5-Second wafer replacement eliminates maintenance which otherwise could take a full day or more, saving valuable time and increasing reliability. Simply withdraw dust cover, lift out any wafer and replace at once. No unsoldering or disassembling. No wire removing. Virtually unlimited choice of switch circuits. Up to 36 wafers per switch as needed.

1¾" x 1½" Rotary Selector Switch, Series RS1S. Manually (illustrated), motor or solenoid operated.

2½" x 2¾" Rotary Selector Switch, Series RS2I. Solenoid (illustrated), manually or motor operated.

3" x 2⅝" Rotary Selector Switch, Series RS3I. Manually (illustrated), solenoid or motor operated.

4" x 4" Rotary Selector Switch, Series RS4I. Motor (illustrated), manually or solenoid operated.

4 THIN DIGITAL & BINARY MODULAR THUMBWHEEL SWITCHES

Only ½" panel space needed per module, 9/16" for lighted type. Instant, clear 1-number-at-a-time readout. Available in permanent or removable wafers in 8, 10 or 12 positions up to 36 switches per modular assembly. Vertical or horizontal positioning.

New Complete Line of Rotary Switches

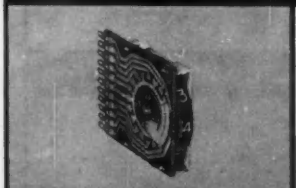
FOR CRITICAL RELIABILITY APPLICATIONS . . .

Sets a New Standard for Serviceability & Flexibility

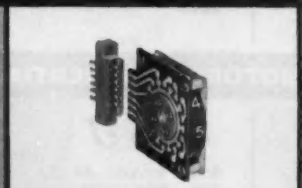
- **Many models presently supplied for military requirements where exceptional reliability is paramount.**
- **Quick changing of programs, configurations, circuits.**
- **Maintenance problems completely eliminated by unique 5-second wafer replacement models.**
- **For lengthy, trouble-free operation, specify CDI switches. Write for technical details today.**

CHICAGO DYNAMIC INDUSTRIES, Inc.

C·D·I PRECISION PRODUCTS DIVISION
1725 Diversey Blvd., Chicago 14, Illinois
Phone: WEllington 5-4600

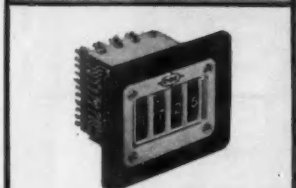


Permanent wafer type, Series TSD-P.

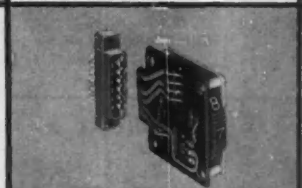


Removable wafer type, Series TSD-R. For continuous operation applications where interruptions must be held to an absolute minimum.

NEW 400-Position Rotary Switch with Maintenance-Saving Removable Wafers, Series RSG. Types RSG-40 (4"x4") and RSG-30 (3"x3") have 20 standard wafers, 1 Geneva control unit and 1 control wafer for handling up to 400 positions. Type RSG-21 (2" x 2") utilizes 10 standard wafers, 1 control unit and 1 control wafer for handling up to 100 positions. Available with any standard multi-position indicating dial.



Permanent wafer type, Series TSB-P.



Removable wafer type, Series TSB-R. For applications where maintenance time is valuable and rapid servicing a necessity.

Unique Multi-Deck Rotary Thumbwheel Switch, Series TM. Available with 2, 3 or 4 XXXP or epoxy p.c. ½" wafers in any combination of 8 or 10 position binary and 8, 10, 12 or 16 position digital switches, all manually operated by a single ¼" thumbwheel. Instant, accurate readability. Integral lighting available.

Announcing a new series of **size 8 servo components** designed for today's high performance systems

hi-*T* or lo-*J*

(HIGH TORQUE) (LOW INERTIA)

EAD's new line of Size 8 servo components are designed to meet the extreme environmental conditions and the reliability required by today's advanced control systems. From a family of six basic units, the design engineer has the selection of servo motors, inertially damped servo motors or servo motors with tachometer generators for "hi-*T*" or "lo-*J*" system needs.

As with all EAD components, these motors can be modified, if necessary, and can be supplied with a wide variety of integral gear reductions.

TYPICAL CHARACTERISTICS

- **26 volts per phase, 400 cycles**
- **Stall power per phase (watts):**
  - **hi-*T* 3.0**
  - **lo-*J* 2.8**
- **Max. power output (watts):**
  - **hi-*T* .40**
  - **lo-*J* .28**
- **Size 8 diameter: .750"**
- **Meets MIL-E-5272, MIL-E-5400.**
- **Ambient temperature: −55°C to +125°C.**

Construction features: precision ball bearings, housing and hardened shaft all of stainless steel.

SERVO MOTORS

hi-*T*

Embraces high torque/watt ratio and adequate acceleration characteristics. Stall Torque, **.35 oz-in.**; Rotor inertia, .66 gm.-cm²; Acceleration, 37,000 rad./sec.²; No load speed, 6500 rpm; Damping coefficient, 36 dyne-cm-sec/rad.; **3.0 watts/phase @ stall.**

lo-*J*

For low time constant and fast response to input signals in systems requiring max. torque/inertia. Rotor inertia, **.17 gm.-cm²**; Acceleration, 104,000 rad./sec.²; No load speed, 6500 rpm; Damping coefficient, 26 dyne-cm-sec/rad. Stall torque, **.25 oz-in.**

SERVO MOTORS with TACHOMETER GENERATORS

hi-*T*

Stall Torque, .35 oz-in.; Rotor inertia, .72 gm.-cm²; Acceleration, 34,400 rad./sec.²; No load speed, 6200 rpm; Damping coefficient, 38 dyne-cm-sec/rad.; **3.0 watts/phase @ stall**; Gen. output, .250 v/1000 rpm; Phase shift, ±10°; Null voltage, 10 mv.; Gen. input, 1.7 watts.

lo-*J*

Rotor inertia, **.23 gm.-cm²**; Acceleration, 77,000 rad./sec.²; No load speed, 6200 rpm; Damping coefficient, 27 dyne-cm-sec/rad.; Gen. output, .250 v/1000 rpm; Phase shift, ±10°; Null voltage, 10 mv.; Gen. input, 1.7 watts. Stall torque, **.25 oz-in.**

SERVO MOTORS with INERTIAL DAMPERS

hi-*T*

Stall torque, **.35 oz-in.**; Rotor inertia, 1.0 gm.-cm.²; Acceleration, 24,700 rad./sec.²; No load speed, 6000 rpm; Damping coefficient, 39 dyne-cm-sec/rad.; **3.0 watts/phase @ stall**; Flywheel damping, 60 dyne-cm-sec/rad.; Corner freq., .98, 2.8 and 18.5 cps.

lo-*J*

Rotor inertia, **.54 gm-cm²**; Acceleration, 32,700 rad./sec.²; No load speed, 6000 rpm; Damping coefficient, 28 dyne-cm-sec/rad.; Flywheel damping, 60 dyne-cm-sec/rad.; Corner freq., .77, 2.8 and 16.4 cps. Stall torque, **.25 oz-in.**

SEND FOR COMPLETE TECHNICAL DATA

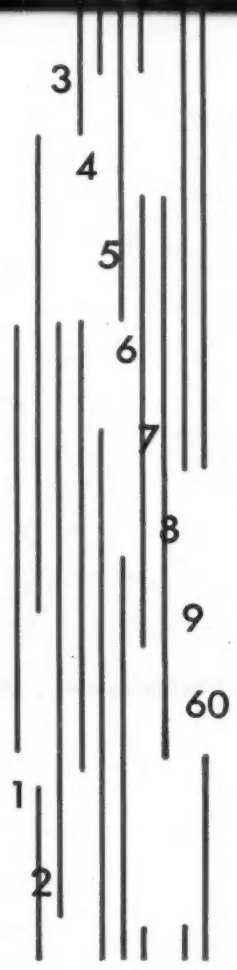
EAD **EASTERN AIR DEVICES, INC.**

SUBSIDIARY OF NORBUTE CORPORATION

375 CENTRAL AVENUE, DOVER, NEW HAMPSHIRE

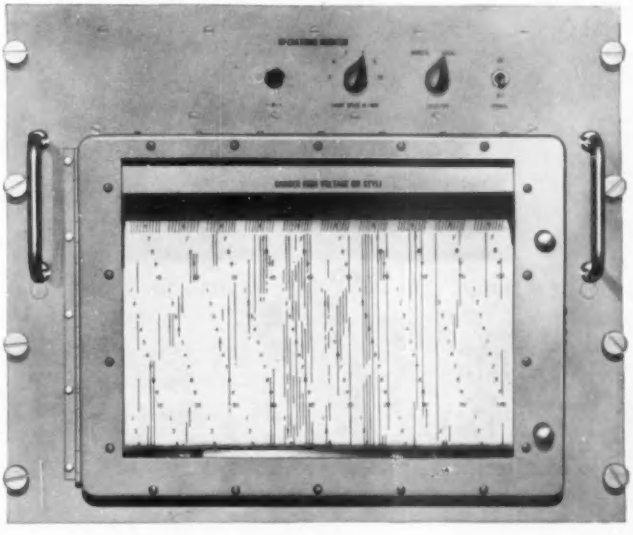
CIRCLE 101 ON READER SERVICE CARD →

verify events permanently in milliseconds

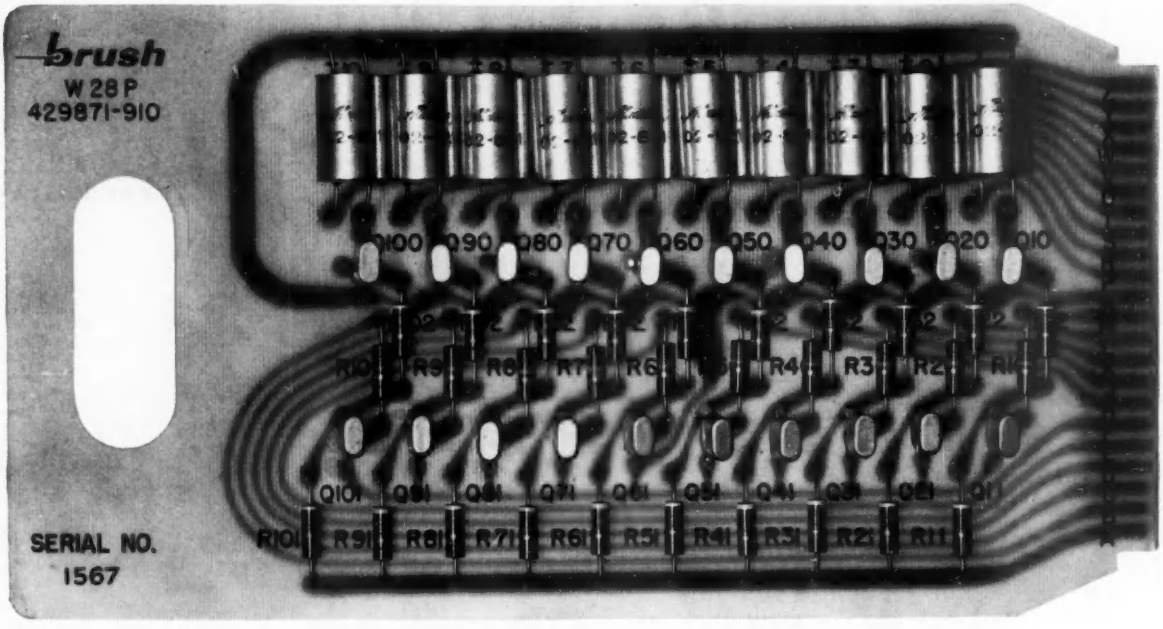


Brush Operations Monitors' response to signals is virtually instantaneous—less than 4 milliseconds. Multiple high-speed events are clearly defined from start to stop, on a common time base—and at rates up to 500 per second. Portable 30 channel or rack-mounting 100 channel models record sharp reproducible traces with fixed-stylus electric writing that provides the utmost in reliability. "Built-in" transistor switching to eliminate relays is optional. No direct writing recording system can match the capabilities of Brush Operations Monitors for industrial and military analysis and control. Write for complete specifications and application data.

brush INSTRUMENTS
DIVISION OF
37TH AND PERKINS CLEVITE CORPORATION CLEVELAND 14, OHIO



compact transistor switching for millisecond monitoring



The new Brush Trans-Switcher eliminates relays—greatly simplifies your problems of operations monitoring. Designed to take full advantage of the fast response and high resolution of Brush Operations Monitors, this compact, solid-state switching unit accepts up to 100 different "on-off" signals in a broad range of pulse shapes and amplitudes. Interchangeable, plug-in decade boards are designed to accept different voltage ranges and modes of operation. Avoid the "black box" approach—specify the *standard* Brush Trans-Switcher for the ultimate in precise, reliable monitoring. Write for complete details.

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DIVISION OF CLEVITE CORPORATION
37TH AND PERKINS CLEVELAND 14, OHIO

GENERAL PURPOSE Control
Dunco 219 Frame relays in three stock contact arrangements
Single Coil
SEQUENCE
NEW! — Dunco Frame 211 relays provide thousands of control sequences
2-Coil
"MEMORY"
NEW! — mechanical latch, electrical reset Frame 255 relays

A COMPLETE RELAY LINE FOR

Simplified, Economical Industrial Control

This dependable Dunco relay "family" paves the way to practically any needed industrial control sequence, "memory" or operational circuitry feature.

Smaller, moderately priced and requiring less operating power, Dunco 219 Frame relays have revolutionized many control panels previously "over relayed" with larger, more costly contactor type units than needed.

Now, in matching types, Dunco offers 255 mechanical latch, electrical reset and Frame 211 sequence relays.

All feature 12-pin plugs with heavy-duty industrial sockets. Contacts are conservatively rated at 10 amperes. Standard 150 volt electrical spacings are used throughout. All three types are designed for maximum control panel simplification and in minimum size for dependable service over millions of operations.

Write for Data Bulletins on any type to Struthers-Dunn, Inc., Pitman, N. J.

STRUTHERS-DUNN

WORLD'S LARGEST ASSORTMENT OF RELAY TYPES

S-D

Sales Engineering offices in: Atlanta • Boston • Buffalo • Charlotte • Chicago • Cincinnati • Cleveland • Dallas • Dayton • Denver Detroit • High Point • Kansas City • Los Angeles • Montreal • New York • Orlando • Pittsburgh • St. Louis • San Carlos • Seattle • Toronto
Exports: Langguth-Cleo Co., New York

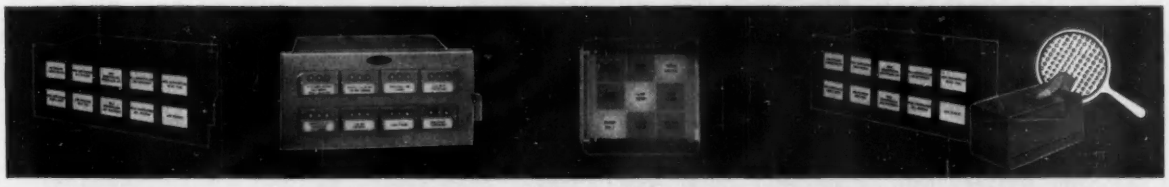
CHOOSE FROM THE

world's largest industrial annunciator line

AS VERSATILE AS YOUR REQUIREMENT

Lessens downtime by giving *instant visual* AND *audible alarms* when an "off-normal" occurs in your process. Time-saving—pinpoints trouble, permits faster correction and resumption of full production.

- Easily expandable universal system—rugged functional construction.
- Variety of sequences—interchangeable plug-in modules.
- Lowest installation cost—trouble-free operation.
- Over 1,000,000 service-proven hermetically-sealed Panalarm plug-in relays in use.



Universal All-Purpose Annunciator System—can continuously monitor all points in your process. Wide choice of visual and audible sequences (optional flashing, ringback, multi-color visual, momentary lock-in, lamp reset, etc.) permits differentiation between new and previously acknowledged alarms.

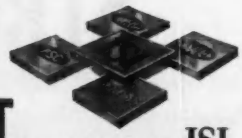
Digital Sequential Annunciator. Sequentially identifies your required off-normal points instantly. Handles any number of total alarm points. Clear binary readout. Millisecond resolution between points.

Miniature Solid State Annunciator—economical, lo-drain, intrinsically safe, no moving parts. Engineered for mounting in most standard miniature instrument cases. Compatible with high speed compact computer applications.

Recording Annunciator has both flashing visual and audible alarm simultaneous with exclusive digital alpha-numerical recording of operations. No time-wasting decoding, no useless blank tape accumulation. Automatic, permanent, unalterable statistical record saves operator's time, reduces chance of operator error, permits closer supervision. Equally effective in manned or unmanned locations.

All annunciators available in a considerable variety of standard sizes, cabinets and sequences to economically fit your exact requirement. Write today for descriptive catalog which also details Panalarm's unique quality features.

Panalarm manufactures the most complete line of annunciators for information and control. For an optimum competitively priced Annunciator System for your plant, consult Panellit engineers. Sales and engineering offices in all principal cities.



PANELLIT A DIVISION OF **ISI** INCORPORATED

7401 NORTH HAMLIN AVENUE, SKOKIE, ILLINOIS • PHONE ORCHARD 5-2500

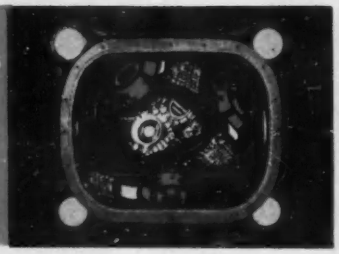
Annunciators • Control Panels • Data Systems • Contract Maintenance and Installation

Inland

Now in Production for Second Generation Servos

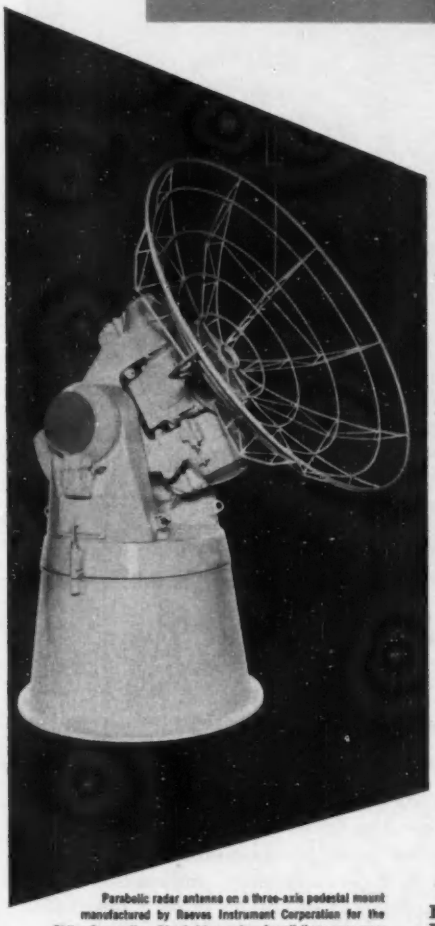
d-c torque motors

peak torques from 0.1 to 3000 pound-feet



Compact pancake d-c torquers in a wide range of sizes are now available for direct drive servo positioning in airborne, shipboard and ground service stabilization and tracking systems.

Miniature, four-gimbaled, Minneapolis-Honeywell inertial navigation platform currently applied to both terrestrial and space guidance systems. All four gimbals are equipped with Inland torquers having a peak output at stall of 60 ounce-inches.



Parabolic radar antenna on a three-axis pedestal mount manufactured by Reeves Instrument Corporation for the Philco Corporation. Direct drive motors for all three axes were provided by Inland. These range in output from 500 to 3000 lb-ft.

Exclusive Commutator and Brush Rigging Design

Patented Inland features make possible powerful d-c torquers in compact pancake shape. More torque, with smaller size and lower power input.

REPRESENTATIVE RANGE OF INLAND D-C TORQUE MOTORS

TYPE	PEAK TORQUE AT STALL	POWER INPUT FOR PEAK TORQUE WATTS @ 25°C	DIMENSIONS, INCHES O.D.	THICKNESS
T-1321	20 oz.-in.	57	1.94	.50
T-2136	35 oz.-in.	42	2.81	.63
T-2108	60 oz.-in.	32	2.81	1.00
T-2907	.85 lb.-ft.	79	3.73	1.09
T-4006	1.8 lb.-ft.	100	5.13	1.25
T-5105	2.7 lb.-ft.	86	6.25	1.31
T-5703	7.0 lb.-ft.	246	7.20	1.63
T-720	11.0 lb.-ft.	327	9.00	1.63
T-8001	25 lb.-ft.	925	10.50	2.63
T-10001	35 lb.-ft.	620	13.69	4.30
T-10004	100 lb.-ft.	1020	12.75	5.75
T-18002	300 lb.-ft.	1300	26.63	5.82
T-18004	900 lb.-ft.	4330	26.50	10.56
T-36001	3000 lb.-ft.	7400	45.0	10.25

For complete data on these or other Inland d-c pancake torquers, address Dept. WE, Inland Motor Corporation of Virginia, Northampton, Massachusetts.

INLAND AMPLIFIERS—Inland makes a complete line of amplifiers for systems duty with Inland torquers, whether in airborne, shipboard, or ground service. Specification sheets available on request.

Factory: Radford, Virginia

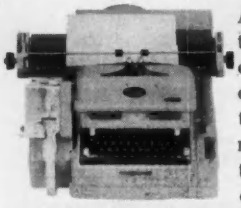
INLAND MOTOR CORPORATION OF VIRGINIA

A SUBSIDIARY OF KOLLMORGEN CORPORATION

NORTHAMPTON, MASS.

Is punched tape really the best input medium for numerical control?

(3 out of 4 machine tool makers say yes!)



Although 8-channel punched paper tape is only one of several numerical control input media, it is fast becoming the standard. Better than three-quarters of all builders of numerically-controlled machine tools now offer punched paper tape control. Why the swing to punched paper tape? There are three fundamental reasons:

1) Paper tape coding is visible, tangible. You can see it, touch it, and with practice even read it.
2) Paper tape is continuous. Unlike cards, it can't get out of order.
3) Paper tape is easy to program—preparation, verification, and reproduction of tapes are all handled on one inexpensive machine, the Friden Flexowriter® (illustrated).

For the machine tool buyer, standardization on paper tape means great savings. It's so much easier (and less expensive) when *one* input system can control *all* of the numerically-controlled machines in a given plant.

If you're thinking numerical control, you'll be way ahead to think *punched paper tape*.

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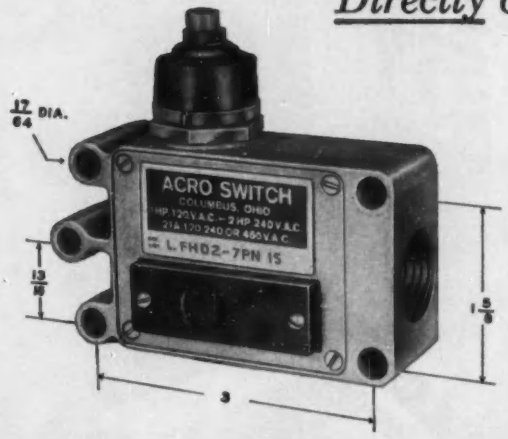
Friden Creates A New World For Business®

Friden

What's new in Acro's metal-clad switches? *It's Acro Lite...gives you a Control Panel Directly on the Switch!*



This year — Acro's 21st — introduces ACRO-LITE — a brand new feature that gives your customers visual evidence of performance — a miniature control panel directly on the switch!

If you specify metal-clad switches in your product line, direct your purchase inquiry to Acro Switch. For Acro makes a complete, reliable line of metal-enclosed switches — that fill your needs for protective housings, with either side or flange mount casings.

NEW! Acro's "21st Anniversary" Acro-Lite Acts as a Control Board Right on the Switch!

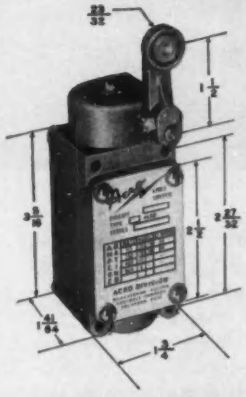
FEATURES:
- Switching unit is replaceable without removing housing from its mounting
- Choice of five different actuators
- Mounting is optional through any of the five mounting holes provided
- Contact arrangement: single pole double throw. Internal switch has screw terminals
- High capacity. Internal switch U.L. approved for 21 amperes at 120, 240, and 480 V.A.C. Also approved 1 HP-120 V.A.C., 2 HP-240 V.A.C.

When Acro-Lite is Lit — the Switch is Powered!

This miniature control panel consists of a neon light, built directly into the side of the switch. When the light is on, there's power flowing through the switch. Or, if your product construction hides the switch from direct view — the light can be mounted remotely for easy visibility. Acro-lite offers high current ratings — 21 Amps — up to 2 HP.

Switching unit completely enclosed in sturdy, lightweight aluminum. Rubber gaskets on all removable parts of the housing. Neoprene boot seals the overtravel plunger, making the switch dust - and splash-proof; assures continuity of repetition patterns. Connecting conduit (switch housing is internally tapped for ½" conduit) completes the seal. Light operating pressures, with close movement differential.

Acro's Small Sized Machine Tool Switch Handles Heavy Load



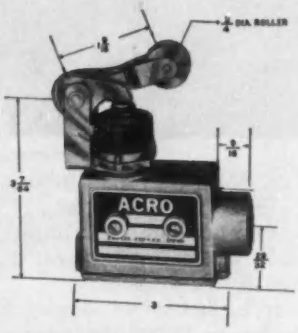
Controls up to four separate circuits for either pilot or line duty. Perfect for machine tool and all production machinery applications. Actuator is adjustable 360° in two planes. Basic switch is easily replaced. Dust-and oil-tight, long mechanical life, long overtravel. Meets NEMA and JIC requirements.

Available in Two Types

Double Action Type actuates switch contacts when actuator is moved either side of "at rest" position. Single Action Type operates from one side of "at rest" position only. Both designed for long life under heavy use.

ELECTRICAL RATING
2 H.P. 230 Volts A.C.
1 H.P. 115 Volts A.C.
20 Amps-250 Volts A.C.

Acro's Model "B" Enclosed Switches



Acro features a complete line of enclosed switches with many different actuators and styles available. Dust and oil type enclosure, with side or flange mounting. Replacement switch kit is available.

Internal Switch Underwriters Laboratory approved

Write for more detailed information on ACRO's metal enclosed switches and take advantage of our free engineering service. We'll be happy to go to work on your specific application problem. District offices located in principal cities.

ELECTRICAL RATING
½ Amp 120; ¼ Amp 240 V.D.C.
15 Amps; 120, 240 or 480 V.A.C.

RELAYS ACRO SWITCHES

"OUR 21st YEAR"

ACRO DIVISION Robertshaw

COLUMBUS 16, OHIO

See our Booth #306 at The Production Engineering Show

The new LFE SM-2 converts digital computer language into a visual message . . . displays alpha-numeric characters, arbitrary or abstract symbols, schematic or logical drawings, graphs, charts and maps.

Twenty-one inch, flicker-free, display tube clearly displays up to 13,000 character messages, or 90 characters per square inch . . . is easily readable with ordinary office lighting . . . features self-contained storage. Brightness and storage are completely independent of the number of characters on any given page.

SM-2 is readily adaptable to data storage and retrieval systems as the on line output device. Typical of this application is LFE's commercially available RASTAD system.

Other applications include air traffic control, intelligence systems, inventory control, production control, process control monitoring, and other applications where information retrieval and display must be simultaneous. Additional specifications available by writing to Dept. C9.

LFE
COMPUTER PRODUCTS DIVISION

LABORATORY FOR ELECTRONICS, INC.
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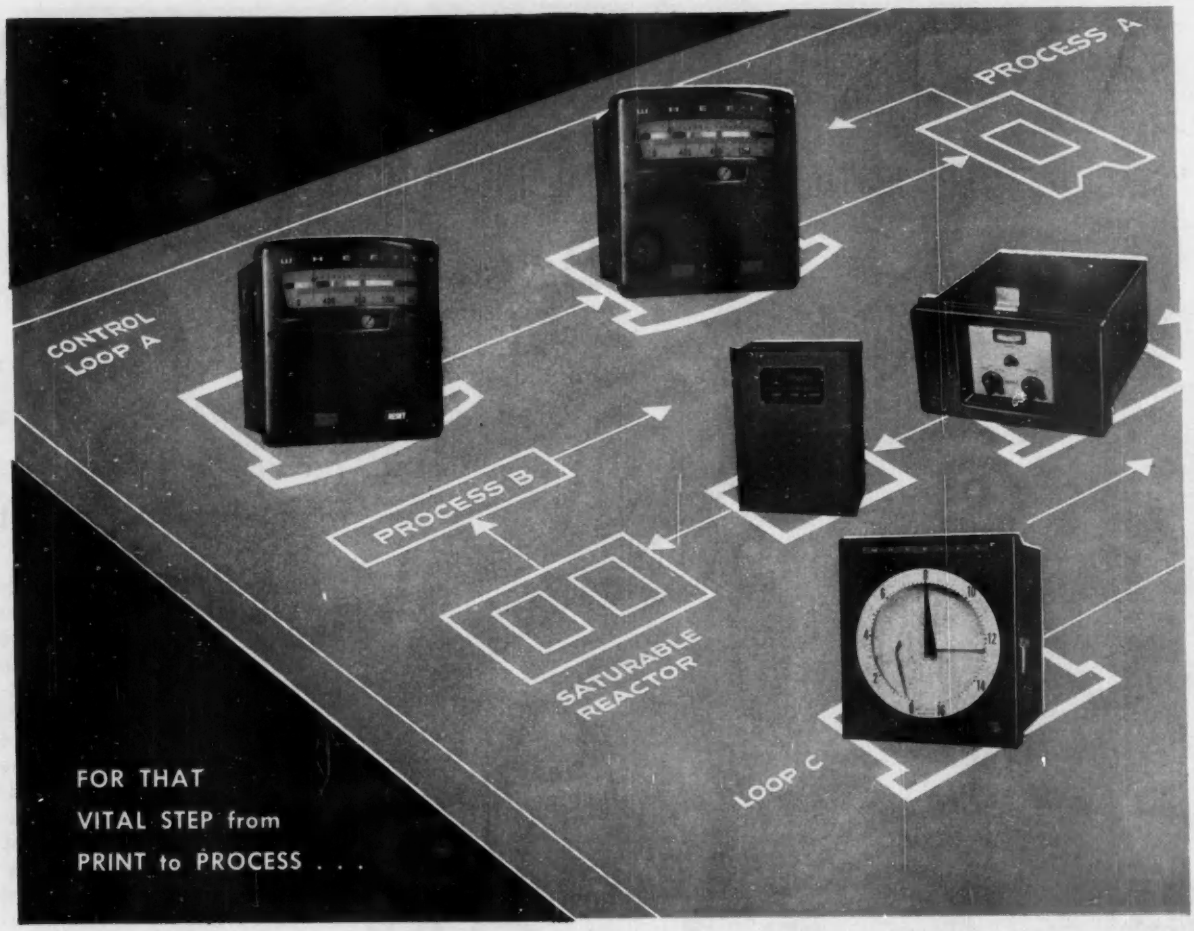

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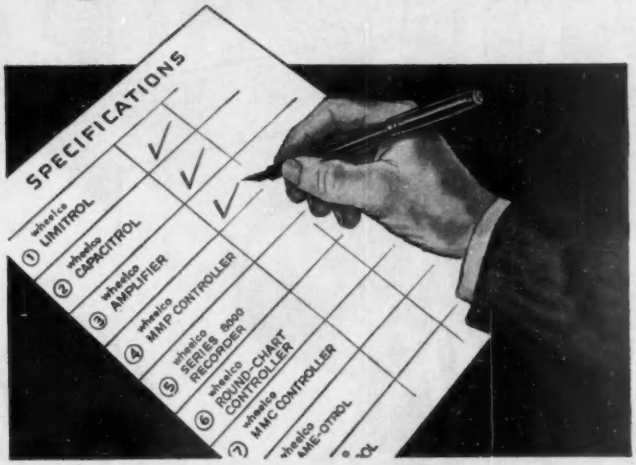
Wheelco Engineers can help you with early planning. Their knowledge of instrumentation can save you time and money. Suggestions on economical and efficient system control are yours for the asking.



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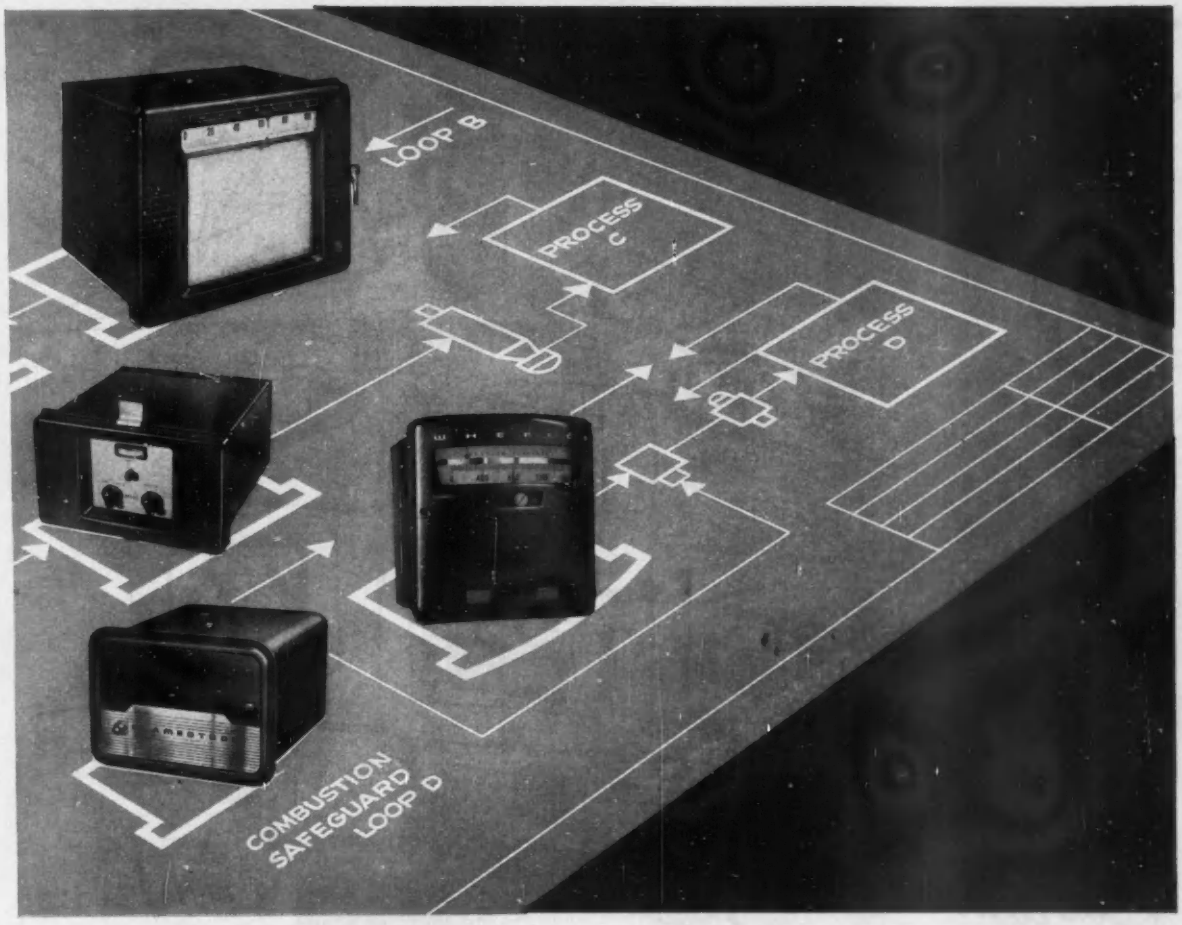

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You can rely on Wheelco to implement your ideas for the best in process control • a broad line of flexible accurate instruments • a solid reputation for instrument dependability • experienced engineering with twenty-five years of process instrumentation • nation-wide service network of Wheelco offices, staffed by skilled engineers • modern plants, production techniques, and a dynamic research and development program. Talk to the man who brings these advantages with him — the Wheelco Sales and Service Engineer. He will help make the vital step from one-dimension planning to three-dimension reality. Why not call him today?

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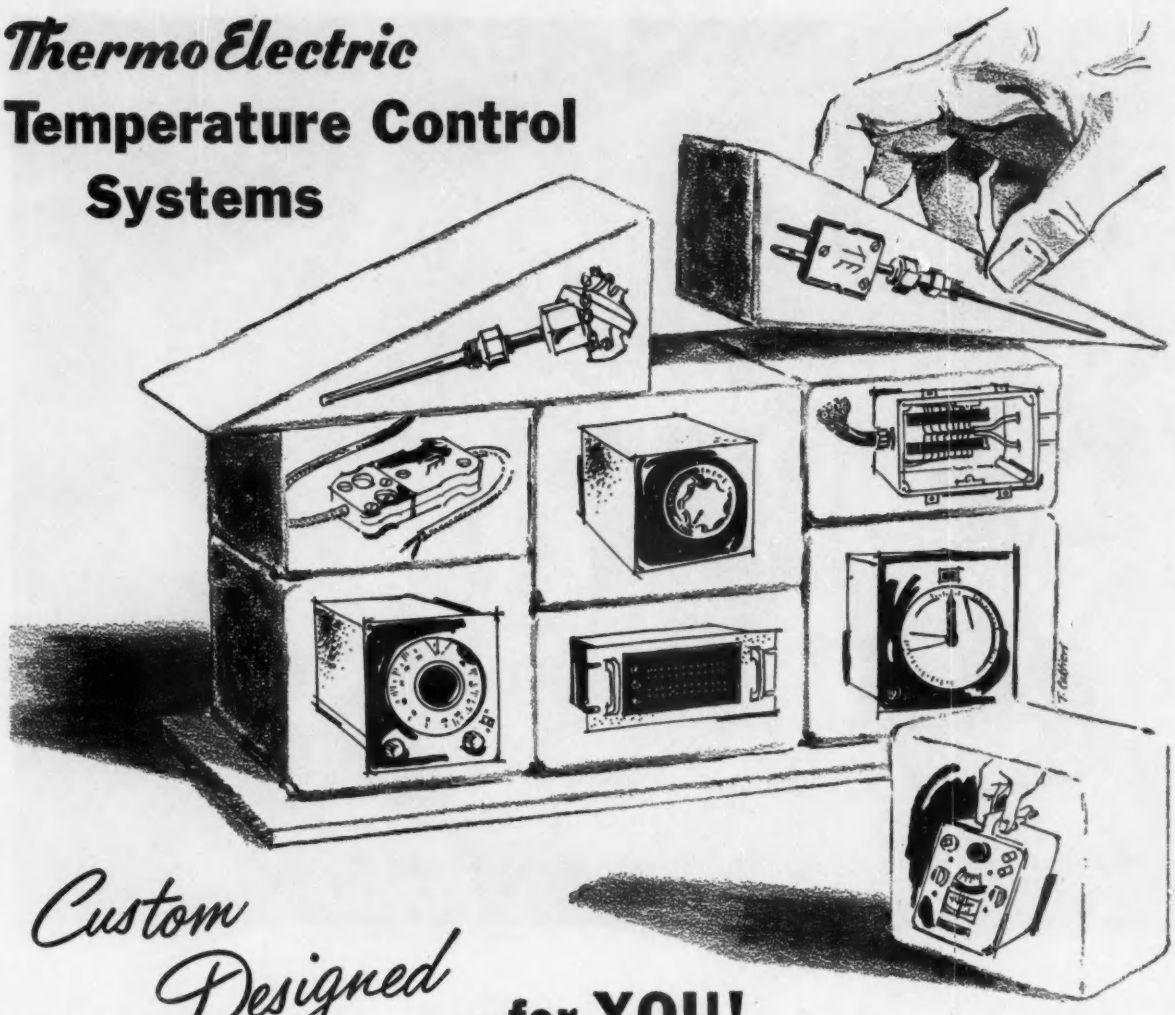
Small Motors • Overdoors and Operators • Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

Thermo Electric Temperature Control Systems



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Thermo Electric advanced systems-building components permit custom designing to satisfy your temperature monitoring, indicating, recording, or controlling requirements, exactly and economically. Starting with T. E. thermocouples—standard or special calibrations—from 1 inch to 66 feet and longer, accessories are carefully selected by T. E. applications engineers to relay any number of signals to your instrument panel. Quick-coupling plug and jack connectors and panels, extension wire and cable are precisely matched to eliminate false emf's. Junction boxes, rotary, key or push-button selector switches are all designed and constructed by T. E. to the highest quality standards.

To monitor, indicate, record or control process variables, T. E. offers the compact Signaling Controller—the Indicating Controller and Indicating Recorder with large, easily-read scales, or special multi-point monitor systems. All instruments have front-set controls, complete in-the-field range interchangeability, ease of service, and feature the new High Gain Relay or Servo Amplifiers with high sensitivity and exceptional stability.

The portable "MiniMite" Indicator with 23" scale and 0.25% scale accuracy, can be used to indicate on-the-spot temperature or for calibration and test work.

Let us assist in building your process control system.

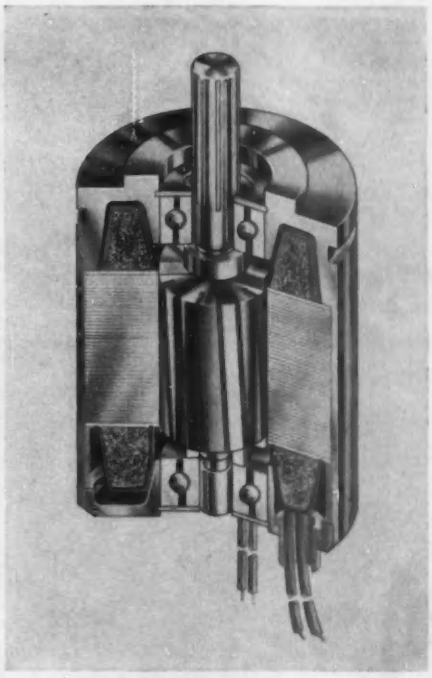
Send application details on your letterhead today to Dept. 11

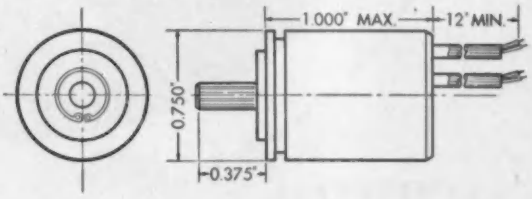
Thermo Electric CO., INC. SADDLE BROOK, NEW JERSEY

In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ontario

For the finest combination of vital performance factors...

Specify KETAY Servo Motors





Performance and reliability in the size 8 servo motor, for example, is underscored by:

- Unexcelled ratio of stall torque to power input at maximum rpm, as related in the chart below.
- High acceleration at stall.
- Efficient operation over the ambient temperature range of—55°C to +125°C.
- Superior "white room" manufacturing, assembly and inspection techniques.

TYPICAL PERFORMANCE CHARACTERISTICS			
Type Number	008E2A	008E2C	008E2D
Excitation Frequency (cps)	400	400	400
Rated Voltage:			
Fixed phase (volts)	26	26	26
Control phase (volts)	26	40/20	26
Input Power at Stall (watts)	1.75	1.75	2.50
Starting Voltage (volts)	0.68	1.0	0.68
Stall Torque (oz. -in.)	0.22	0.22	0.30
Ratio Stall Torque to Total Power Input	0.060	0.060	0.060
Rotor Inertia (gm. cm^2)	.414	.414	.414
Acceleration at Stall (rad./$sec.^2$)	36,000	36,000	53,000
No Load Speed (rpm)	6,500	6,500	6,500
Temperature Rise at Stall (°C)	50	50	60
Operating Temperature Range (°C)	−55 to +125	−55 to +125	−55 to +125

For more information on these or any other of the complete line of Ketay Servo Motors and/or motor generators from size 08 to size 23, 26 or 115 volt, 400 or 60 cycle excitation, please write.

NORDEN

KETAY DEPARTMENT

NORDEN DIVISION

UNITED AIRCRAFT CORPORATION

COMMACK, LONG ISLAND, NEW YORK

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Behind that storied global traveler Phineas Fogg was his valet and navigator Passepartout. Tomorrow's space "Phineas Foggs" will depend on a sophisticated electronic Passepartout to guide their vehicles to the fringe of space and return—in 100 minutes.

Arma is ready for that era. As developer and producer of the first all-inertial guidance system for Air Force ICBMs, Arma has the knowledge, facilities and people to meet the challenge of navigating a manned glider in near space.

Inertial guidance offers important advantages: self-containment . . . low cost . . . immunity to communications failure . . . positive position calculation . . . no time lag in making course corrections . . . a minimum of ground support equipment.

Arma is developing smaller and better inertial systems for use in the years ahead that employ subminiature computers, low threshold accelerometers, gyros suspended in liquid metal and other advanced techniques in inertial instrumentation.

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Engineers: Write to E. C. Lester at ARMA about career R&D opportunities.

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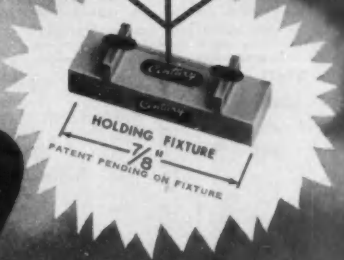
THE MODEL 711

Strainistor

Ultra Sensitive Strain Sensing elements.

60 to 70 times greater Sensitivity than other metal strain gauges

FIRST COMMERCIALLY AVAILABLE!



- Strain sensitivity 120-140
- 120 Ohm nominal resistance
- Resistance change linear with strain.
- Negligible hysteresis
- Suitable for static and dynamic measurements.
- Combination mounting and handling fixture with each Strainistor.

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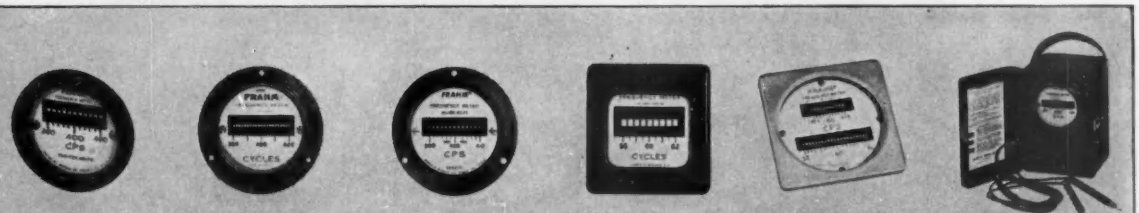
by Biddle SINCE 1910

15 to 1500 cps
(Special up to 1700 cps)
2 to 62 reeds
•
Molded Plastic
or Metal Cases
•
Sealed if required
•
2½" to 8½"
•
Panel Mounting
or Portable

The inherent simplicity and unfailing accuracy of Frahm Resonant Reed Frequency Meters have gained wide acceptance for them in many fields.

The James G. Biddle Company introduced the first vibrating reed instruments in this country over 40 years ago. Throughout these many years our ability and our facilities, for producing only the highest quality instruments, have steadily improved. Our many years of experience, study of materials, processes, and controls, are your assurance of satisfactory performance over long periods of service.

Frahm Frequency Meters are available in switchboard, miniature and portable types in a wide variety of ranges for frequencies from 10 to 1500 cps or even to 1700 cps for special applications. Specially designed instruments can be made to your specifications. We invite your correspondence regarding applications which require special modifications of range, methods of actuating, scale graduations or other design characteristics. Write for our bulletin which contains complete specifications and prices . . . BULLETIN 32 EEM



Catalog 2997, 2½" round metal case—380-420 cps

Catalog 5097, round —380 to 420 cps, 100-150 volts (3½")

Catalog 4890, round 3½" case—400 cps, 1 cycle interval

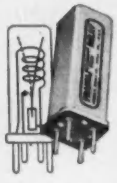
Catalog 4964-2 rectangular — 58.0 to 62.0 cps, 100-150 volts

Showing a 4½" metal case with square bezel, special range

Portable Type with a Miniature Round Frequency Meter (3½")

FRAHM RELAYS AND OSCILLATOR CONTROLS

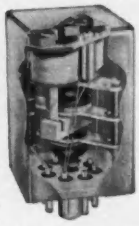
—for selective calling, remote operation, supervisory control, data transmission, telemetering, and monitoring.



The transmission of a number of control signals over a single communication circuit of any type is simplified by the use of these components.

REED RELAYS act like bandpass filters with narrow response bandwidth which operate on SPST contact—available with any one single nominal response frequency for each reed in them within the range from 20 to 1000 cps.

FRAHM ROC RESONANT REED OSCILLATOR CONTROLS are circuit components for electric oscillators—they maintain oscillator output frequency within close limits—also used as electro-mechanical bandpass filters.



Applications include: electrical and acoustical measurements, electrical communication systems (selective calling), remote operation and supervisory control of machinery and apparatus, electrical computers and telemetering systems, electro-mechanical bandpass filters.

Frahm ROC Oscillator Controls are available with any one nominal control frequency between 20 and 1100 cps—constant within ±0.15% of the nominal control frequency.

We particularly encourage inquiries on special applications.

Write for Bulletin on Reed Relays —33 EEM . . . and ROC Oscillator Controls—34 CE

Cat. Number	Range Cycles	Number of Reeds	Interval between reeds cycles	Type of Case	Sealed	Accuracy %
2955	45—55	11	1.0	2½" metal	Yes	0.3
2956	47.5—52.5	11	0.5	" "	Yes	0.3
2966	55—65	11	1.0	" "	Yes	0.3
2967	57.5—62.5	11	0.5	" "	Yes	0.3
2995	390—410	11	2.0	" "	Yes	0.3
2997	380—420	11	4.0	" "	Yes	0.3
2996	375—425	11	5.0	" "	Yes	0.3
4850	49—51	21	0.1	3½" metal	Yes	0.1
4860	59—61	21	0.1	" "	Yes	0.1
4861	58—62	21	0.2	" "	Yes	0.1
4890	390—410	21	1.0	" "	Yes	0.1
4956	47.5—52.5	11	0.5	3½" plastic	No	0.3
4957	48.0—52	11	0.4	" "	No	0.3
4959	48.0—52.0 58.0—62.0	10	1.0 1.0	" "	No	0.3
4964	58.0—62.0	9	0.5	" "	No	0.3
4965	56.0—64.0	9	1.0	" "	No	0.3
4966a	58.0—62.0	11	0.4	" "	No	0.3
4966	57.5—62.5	11	0.5	" "	No	0.3
4967	55.0—65.0	11	1.0	" "	No	0.3
4996	375—425	11	5	" "	No	0.3
4997	380—420	11	4	" "	No	0.3
5066	55—65	21	0.5	" "	No	0.3
5067	50—70	21	1.0	" "	No	0.3
5097	380—420	21	2	" "	No	0.3
5098	360—440	21	4	" "	No	0.3
6405	45—55	21	0.5	4½" metal (sq. bezel)	Yes	0.3
6410	55—65	21	0.5	" " " "	Yes	0.3
6497	380—420	21	2.0	" " " "	Yes	0.3
6498	360—440	21	4.0	" " " "	Yes	0.3
6505	44—56	25	0.5	5½" metal square	No	0.3
6510	54—66	25	0.5	" " "	No	0.3
6515	48—72	25	1.0	" " "	No	0.3

Voltages 100 to 150 v—D.C. resistance 100 ohms per volt—Instruments meet MIL Specification

Cases meet ASA standard diameter dimensions

3½" meters available in round plastic, round metal (sealed or unsealed), or round plastic with square bezel

Portable instruments available in all ranges shown with 3½" cases

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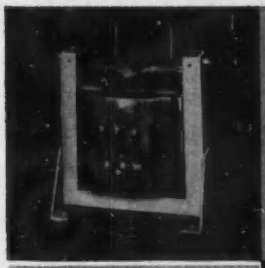
AUTOMATIC CONTROL PRODUCTS



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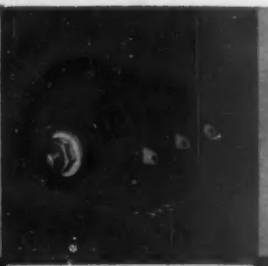
"super power", high performance, high power, special purpose (servo, low level, bi-stable, multi-stage and educational) in a complete range of sizes and voltage ratings.
Series 1000 Bulletins.



SELENIUM RECTIFIERS
grain-oriented (T. M.) for greater rectifying efficiency, lower cost per watt. Cell ratings from 18 to 36 volts. Microamperes to 1000 amperes.
Series 3100 Bulletins.

SILICON POWER RECTIFIERS
2, 8, 12, 18 and 35 ampere sizes. Excellent operating characteristics, uniform quality, greater economy.
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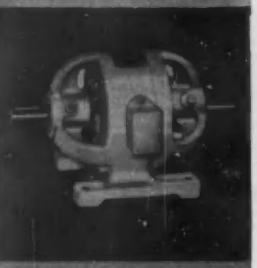
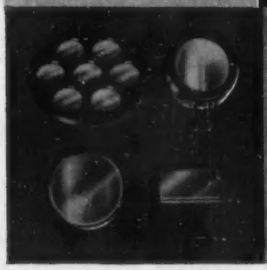
magnetic particle clutches and brakes. Smooth, flexible operation, fast response, torque independent of speed, long life
Series 6000 Bulletins.





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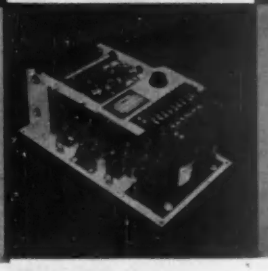

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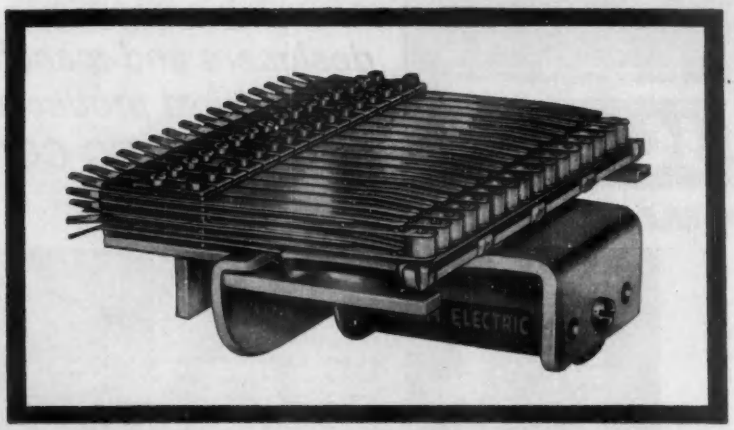

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Where reliability is a must—North 700 Series "gang" relays combine fast action multiple circuit switching capabilities with the proven dependability of a telephone type open relay for use in computers, sorting and punching machines and similar applications. North 700 Series relays provide up to 16 pile-ups and are available to 32 form A or to 16 form B or form C contact arrangements.

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For applications where the small number of relays in a switching system make a common DC power supply uneconomical, the North 7300 Series is available with AC rectifiers.

North "gang" relays can be supplied with Double Gold Alloy or Solid Silver contacts, with solder type or AMP #78 type contact terminals, and with 12, 24, 48, 75 and 110 volt coils (110 V.A.C. for 7300 Series). Operating speeds range from 30 MS to 70 MS at approximately 2.2 watts. Faster speeds can be obtained with increased power.

For detailed specifications on North "Gang" 700, 7200 and 7300 Series relays, write...

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NORTH ELECTRIC COMPANY

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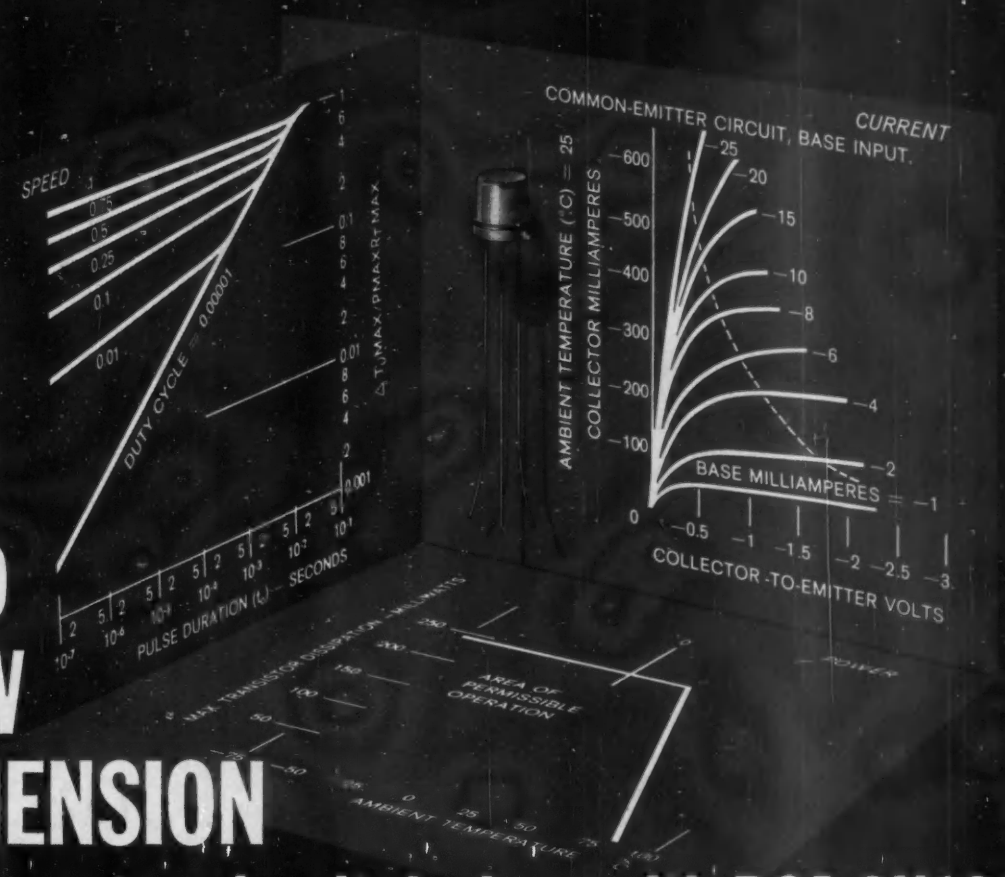

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to computer circuit designs with RCA 2N1384

High current, high dissipation and high switching speed are combined in new germanium p-n-p drift-field transistor for use in saturating circuits in industrial and military data-processing systems

Now you can specify a germanium drift-field computer transistor designed to meet the stringent requirements of today's saturated switching circuits. The new RCA 2N1384 in the JEDEC TO-11 package, provides the following outstanding characteristics:

- *Exceptionally High Collector-Current Rating*—Maximum collector-current rating is 500 ma
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- *Ultra High Speed*—Rise time of the 2N1384 in an inverter circuit at 25°C ambient is 0.08μsec. Typical gain bandwidth product of 35 Mc.
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- *Immediately Available*—and priced for your mass production requirements.

Call your RCA Field Representative today. Or write RCA Semiconductor and Materials Division, Commercial Engineering, Section I-56-NN, Somerville, N. J.

RCA 2N1384	
Maximum Ratings, Absolute-Maximum Values:	
COLLECTOR-TO-BASE VOLTAGE	−30 max. volts
COLLECTOR-TO-EMITTER VOLTAGE	−30 max. volts
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COLLECTOR CURRENT	−500 max. ma
EMITTER CURRENT	500 max. ma
TRANSISTOR DISSIPATION:	
At an ambient temperature of 25°C	240 max. mw
At an ambient temperature of 55°C	120 max. mw
At an ambient temperature of 71°C	56 max. mw
AMBIENT-TEMPERATURE RANGE:	
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In the past 2 years thousands of Servomatic motors have proven the inherent advantages of this Taylor innovation. Heart of the 90J (pneumatic) and 700J (electronic) recorders, it puts TRANSCOPE Recorders in a class by themselves. It is the most reliable device yet developed for converting an input signal into an accurate record. The tremendous power of these Servomatic motors—150 times greater than the bellows type (pneumatic), over 1,000 times greater than galvanometer systems (electronic)—gives you all these advantages:

- Greater accuracy than ever before—½ of 1% in standard instruments, ¼ of 1% optional.
- Threshold sensitivity of 0.1% to input signal.
- 3 months' ink supply mounted on the pen—no troublesome capillary.
- Lifetime recording accuracy—no critical pen pressure.
- No flimsy linkages and levers.
- Truly rectilinear chart—no curved time lines.

Plus these optional features: alarm contacts—retransmitting potentiometer—function generation—digital output with encoder discs.

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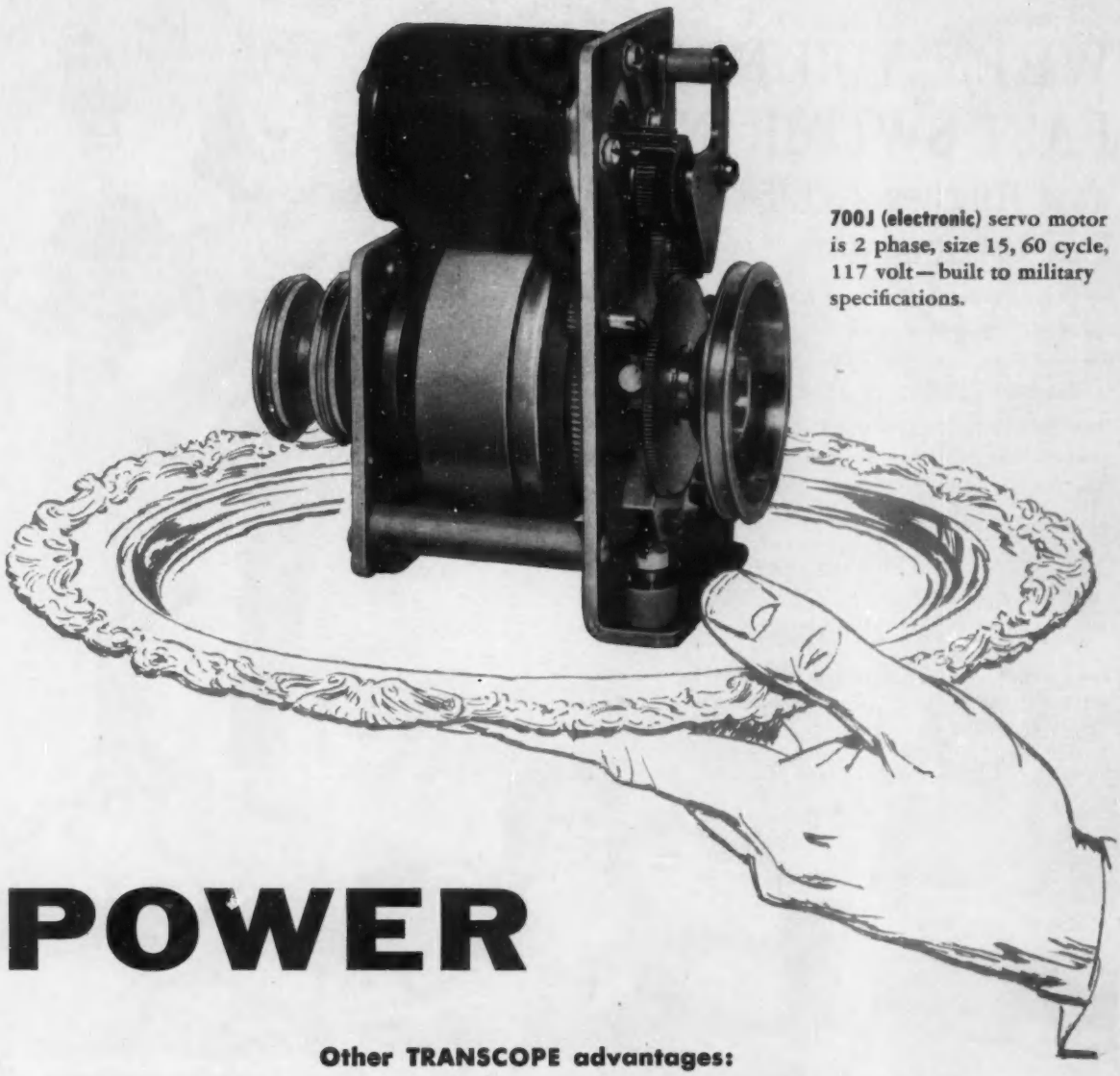
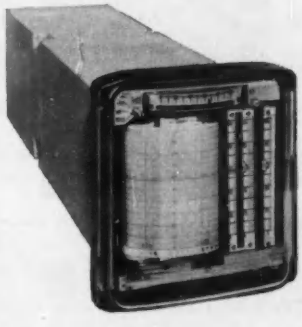
Ask your Taylor Field Engineer for full details of all the many superior features of TRANSCOPE servo-operated recorders. Or write for Bulletin 98286 (pneumatic) or 98335 (electronic). Taylor Instrument Companies, Rochester, New York, or Toronto, Ontario.

See it demonstrated at the ISA Show, Booths 1432-36; 1531-35



700J (electronic) servo motor is 2 phase, size 15, 60 cycle, 117 volt—built to military specifications.

POWER



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Here are the fastest switching p-n-p silicon mesa transistors ever developed. Look at these outstanding features: Typ. f_T of 75MC... thin base region...low stored base charge...low t_d t_r t_s t_f...β of 1.5 min at 50MC...β of 1.75 typ. at 50MC...low collector capacitance. These transistors have good high-level gain characteristics, exceptional low-level gain characteristics, plus high breakdown voltage. They give excellent performance at low voltages, and they are *outstanding* for high-voltage switching.*

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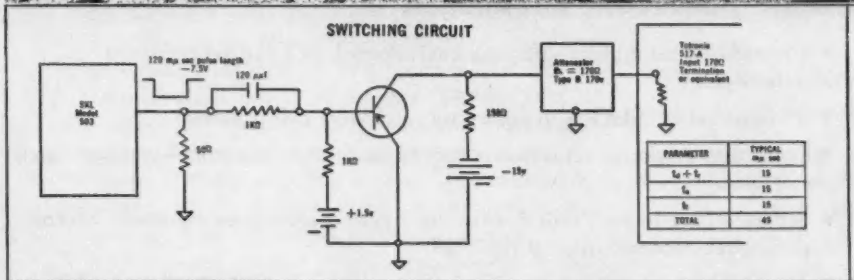
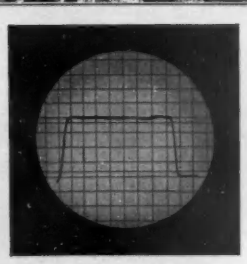
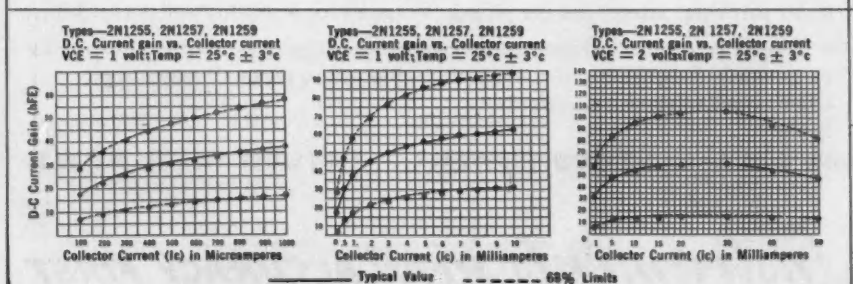
There is a Hughes sales office or authorized distributor in your area. Give them a call today. Or, if you prefer, write Hughes Semiconductor Division, Marketing Department, Newport Beach, California.






Types—2N1255, 2N1257, 2N1259
D.C. Current gain vs. Collector current
VCE = 1 volt; Temp = 25°c ± 3°c
D-C Current Gain (hFE)
Collector Current (Ic) in Microamperes
Types—2N1255, 2N1257, 2N1259
D.C. Current gain vs. Collector current
VCE = 1 volt; Temp = 25°c ± 3°c
Collector Current (Ic) in Milliamperes
Types—2N1255, 2N 1257, 2N1259
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68% Limits

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Intense, white light — 70 times brighter than previous model (4.2 million candlepower on low-speed range).

Short-duration light flash (1 to 6 μsec) "freezes" motion . . . practically eliminates blur . . . lets you clearly see details that are invisible with other commercial stroboscopes.

Long-throw beam reaches into machine innards — made possible by basic new flash tube developed exclusively for this instrument.

Measures speeds directly with ±1% accuracy up to 25,000 rpm . . . useful to at least 250,000 rpm.

Unique carrying case provides full enclosure for protection against damage and doubles as an adjustable stand for convenient bench use.

Pivoting lamp rotates 360° horizontally and 180° vertically.

One simplified dial and range control adjusts rate of flash — eliminates errors accidentally caused by reading wrong scale.

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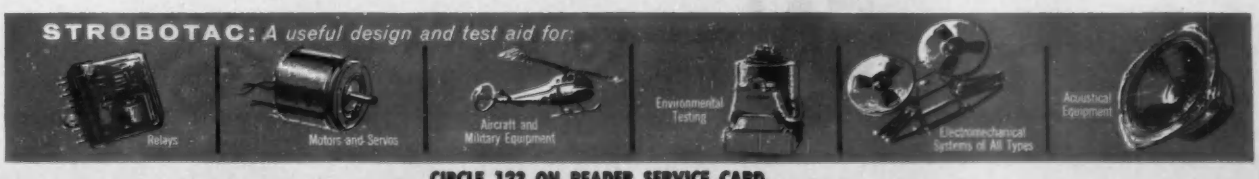
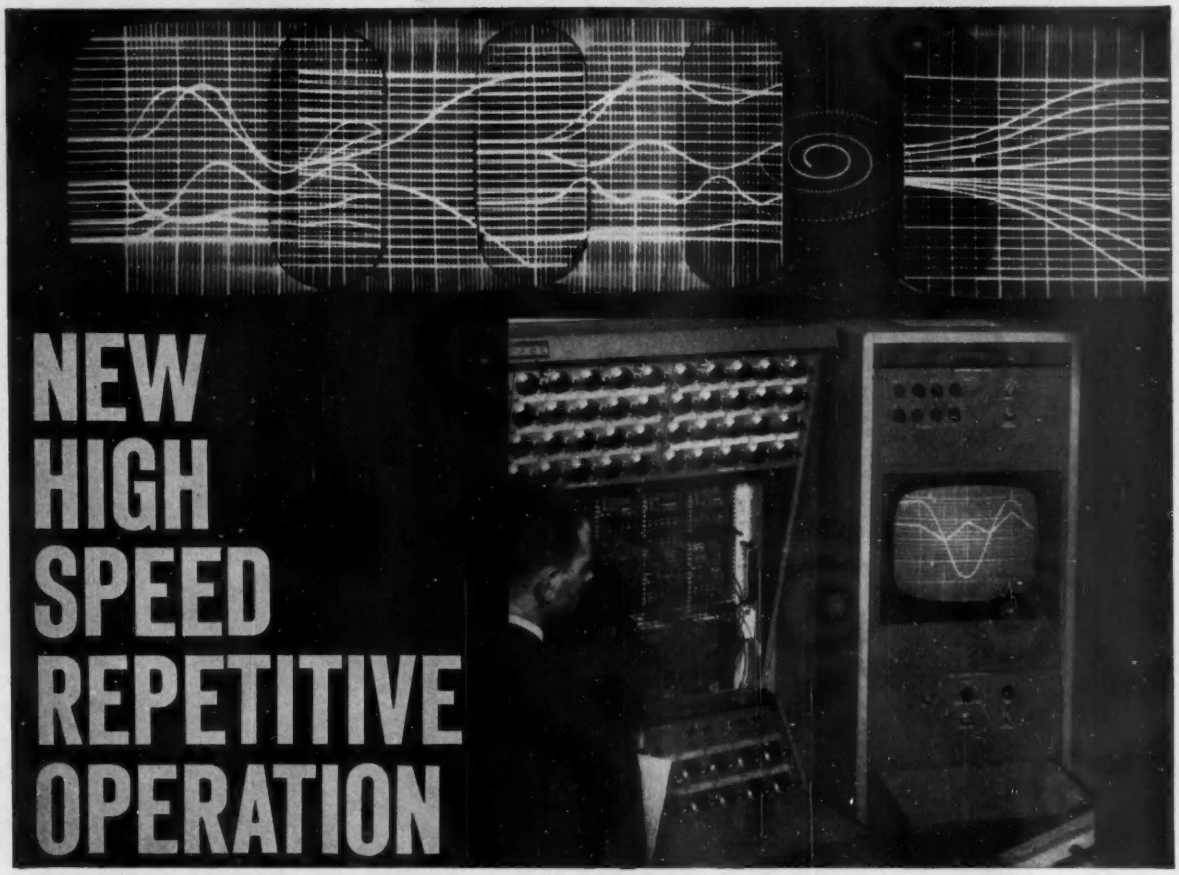


CIRCLE 123 ON READER SERVICE CARD



NEW HIGH SPEED REPETITIVE OPERATION

DRASTICALLY CUTS ANALOG COMPUTATION TIME

The new EAI high speed repetitive operation system is ideally suited to systems design work because it produces solution repetition rates of 10 to 50 per second with *no loss of real time accuracy.* Used with Electronic Associates, Inc. Model 231R analog computer, it provides instantaneous change from real time operation to high speed repetitive operation by a single control . . . requires no re-patching . . . allows real time recording of selected solutions.

This newly developed system for PACE® analog computers can be used as a highly accurate and extremely versatile method for solving a variety of computational problems with greater speed and precision. It is an especially useful engineering tool for design problems involving simulation of servomechanisms, optimization of systems, solution of boundary value problems and mathematical 'model building'. High speed repetitive rates insure rapid approximation of optimum system parameters for control systems and determination of stability regions.

Outstanding features of the EAI high speed repetitive operation system include—

- **solution repetition rates of 10 to 50 solutions per second**
- **precision crystal oscillator control of display unit timing**
- **computer repetitive rate remotely slaved to precision crystal oscillator**
- **switched control of compute time with continuous control between steps**
- **electronically generated display grid . . . constant for repetitive rates**
- **simultaneous display of up to eight variables**

For complete details write for Bulletin AC-6034 describing the new EAI high speed repetitive operation system.

EAI ELECTRONIC ASSOCIATES, INC. *Long Branch, New Jersey*

The Impact on Labor

As control engineers solve the technical problems to make automatic systems feasible in the plant, one nontechnical problem will need prompt attention too: how to ease the pain of local disturbances caused by the installation of automatic systems that reduce the size of the working force. Until recently, no labor union would go on record opposing the installation of automatic equipment, but the situation is about to change.

Scary statistics

Labor is now scared of automatic equipment. Union leaders have been studying some dreary (to them) statistics: For example, between 1947 and 1959 the number of American production workers declined by 500,000, while the Federal Reserve Board Index of Manufacturing Production showed an increase of 35 percent. In manufacturing, during the six years from 1953 to 1959, total employment fell by 6.3 percent to 16.1 million, while factory production workers totals declined by 11.6 percent.

The United Steelworkers Union blames the permanent loss of 100,000 jobs on automatic equipment. In the years from 1948 to 1959, production in the chemical industry increased by 80 percent while the number of production employees declined slightly. Over this same 11-year period, auto production has increased while the size of the work force has shrunk substantially—by 130,000 in Detroit alone in 10 years.

Other industries report a similar downward trend. In railroading, employment has dropped from 1 million in 1956 to 783,000 in 1959, though railroad traffic did not decline. In coal mining 491,000 workers produced 445 million tons in 1937; in 1958, 195,000 workers produced 410 million tons.

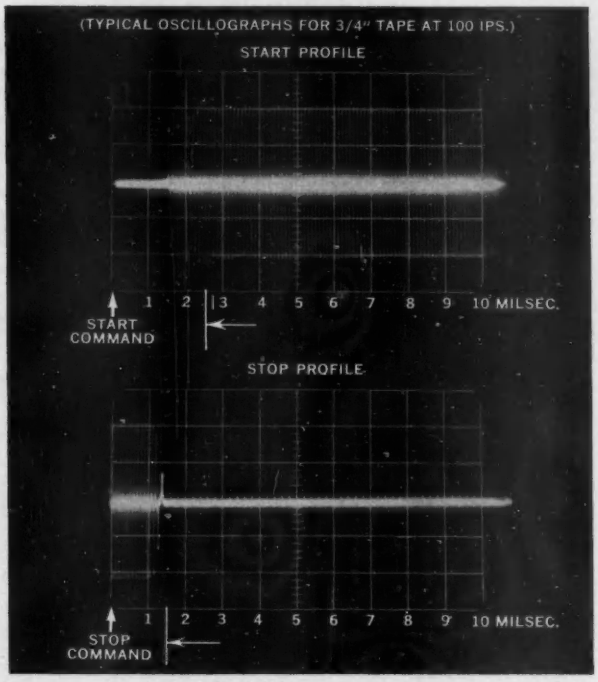
While production employment has been sliding, the number of nonproduction workers has been growing—by 15 percent to 3.9 million in the six years from 1953 to 1959. But the growth is not enough to offset the slide in production workers.

Union proposals

The unions have a lot of ideas as to how to stem this reduction in working forces. AFL-CIO President George Meany wants a 35-hour week required by Federal law. President David J. Macdonald of the USW is asking a legislated 32-hour week. Here's a rundown on some other proposals:

- United Auto Workers President Walter Reuther proposes a technical clearinghouse—a commission on technological change which would submit recommendations to Congress and the White House to "insure that the social gains and costs of technological progress be fairly shared".
- AFL-CIO Communications Workers propose a "Bureau of Automation" to recommend how to combat unemployment and share the gains made possible by automatic equipment.

HERE'S PERFORMANCE...
FOR DIGITAL, MAGNETIC TAPE SYSTEMS


(TYPICAL OSCILLOGRAPHS FOR 3/4" TAPE AT 100 IPS.)
START PROFILE
1 2 3 4 5 6 7 8 9 10 MILSEC.
START COMMAND
STOP PROFILE
1 2 3 4 5 6 7 8 9 10 MILSEC.
STOP COMMAND

The Potter 906 II gives you the highest performance and reliability at savings up to 1/3 the cost of ordinary tape handlers. Potter has been given complete responsibility for tape sub-systems in some of the most widely sold computers. Potter's many years of concentrated specialization in tape system designs assures computer manufacturers of performance and dependability at costs that give them a competitive advantage in today's market. Computer users, too, are specifying Potter tape systems for lower rental costs, fewer service problems, and less down time. The Potter 906 II Tape Handler is being specified by more and more manufacturers and computer users because of the kind of performance proven by the clean Start-Stop profiles above and because the 906 II offers such other advantages as: ● Full forward-reverse cycling with 1" tape at 120 ips. ● Low skew tape guide ● High density: 450,000 8-bit characters per second can be recorded on 1" tape by using the 906 II with the Potter Contiguous Double Transition System. ● Transistorized control of all functions. ● Simplified packaging for easy maintenance. Write for detailed specifications, prices and delivery information on the 906 II and see proof that you get higher performance and greater economy from a tape system specialist.

Potter 906 II magnetic tape transport in the custom designed M 3340 cabinet.

POTTER INSTRUMENT COMPANY, INC.

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In addition, other union leaders have offered a variety of suggestions as to how to ease the impact of automatic equipment:

1) Introduce such equipment gradually so that normal attrition —quits and retirements—offset the effects of less employment.

2) Reassign jobs and retain those displaced.

3) Shift workers throughout the company in different plant jobs or in different plants.

4) Distribute severance pay and supplementary unemployment benefits for those displaced by the automatic machines.

But none of these proposals provides the whole answer to automation. Retraining, for example, is often easier to suggest than to do. Middle-aged employees are sometimes not retrainable. And there is serious doubt whether every machinist displaced by programmed control can be retrained to be a computer programmer, which is a category of employment in short supply. Workers are often unwilling to move to new geographical locations, too. And management sometimes cannot gear a new installation of automatic equipment to attrition—the installation has to be made at one time.

A better way

What looks like the best way to solve the disturbance problem is a joint management-labor admission of responsibility and a willingness by both to help. Although most unions and most managements are not yet ready to admit such responsibility, there are a few pioneering programs blossoming:

On the waterfront

▶The Pacific Maritime Association has an arrangement with two groups, the International Longshoreman's Union and the Warehousemen's Union, in which a $1.5 million fund was collected by employer payments to buy time for a study of: 1) changes made by labor saving machinery, 2) savings to employers because of such changes, and 3) how such savings should be shared.

The goal of the fund is to guarantee the same work force with allowance for normal attrition, at the same time guaranteeing the employer the right to make changes in equipment without restrictions or reprisals by the union.

In food processing

▶Armour and Co. has an unusual agreement with the Amalgamated Meat Cutters and Butcher Workmen and the United Packinghouse Workers. Armour agreed to finance a $500,000 fund, over a two-year period, by a royalty payment plan (a penny for every hundredweight of meat products shipped) to "cushion whatever unemployment may arise through the introduction of automation" in meat packing. The fund is handled by a tripartite committee authorized to study problems arising from modernization, to develop solutions such as retraining or job relocation, and to consider other methods of promoting employment opportunities.

Since the fund was set up, Armour has closed six plants; its employment has dropped from 60,000 to 40,000 in five years. When its latest plant was closed, a 50-year old facility in Oklahoma City, the company provided severance pay for the plant's 400 workers and sent two University of Illinois professors to the scene to help employees. The twosome has been interviewing the displaced employees to determine their work background and future employment possibilities.

In addition, other experts hired under the Armour plan are

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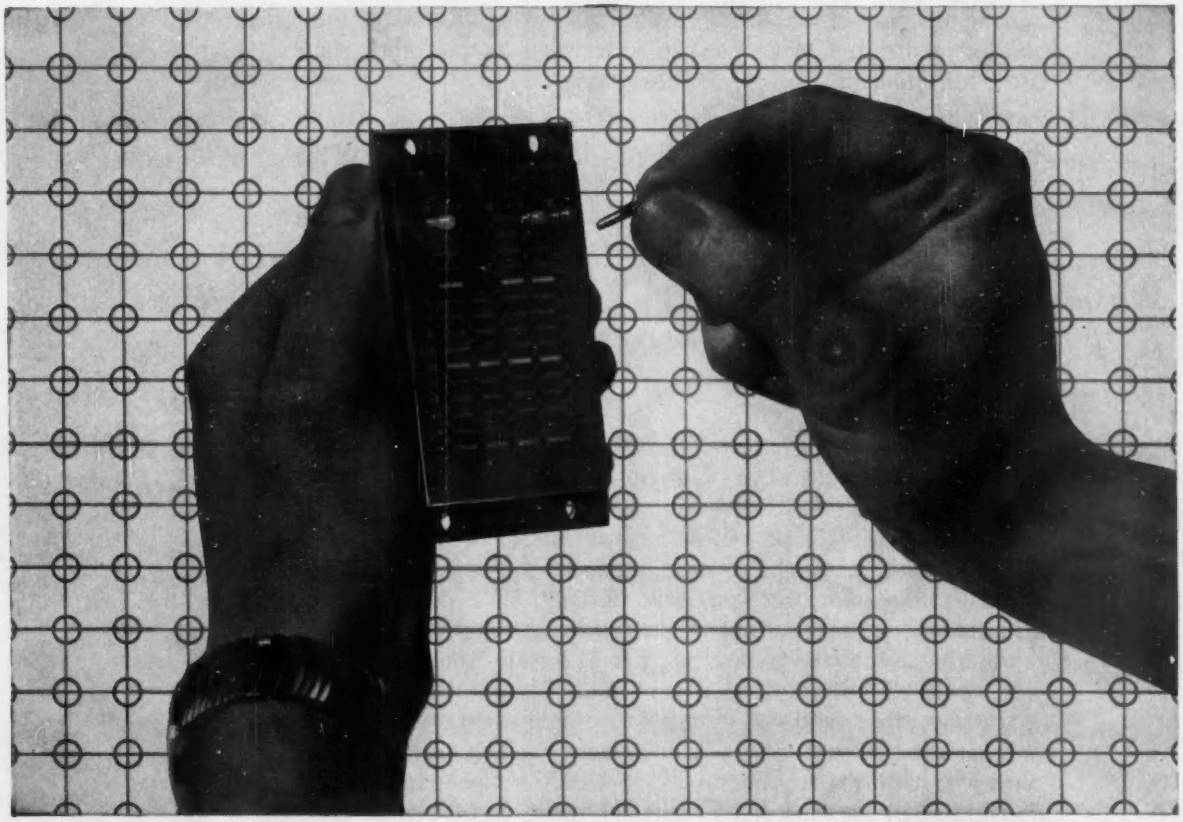
You can use these PINBOARDS as modular building blocks for instrumentation applications, automated tooling, test equipment, data processing . . . any variety of size and grid arrangements in multiples of a basic 15 x 5 hole pattern. Contact springs can be bussed in any combination desired. And for safety, there are no exposed conducting surfaces on the rear side of the board. The conducting area of the pin is safely inside board before contact is made with mating springs.

AMP PINBOARDS are factory pre-wired to your specifications . . . with standard or special silk screen legends. Designed for simplicity . . . flexibility . . . reliability . . . with three amperes continuous current rating.

Write for complete specifications.



AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

AMP products and engineering assistance are available through subsidiary companies in: Australia • Canada • England • France • Holland • Italy • Japan • West Germany

studying the economic future of the meat packing industry, the problems of transferring workers from a closed to a still-operating plant, and the skills needed for new automatic equipment.

In steel

▶Kaiser Steel Co. and the United Steelworkers signed an agreement last year to set up a tripartite committee to recommend "a long range plan for equitable sharing among the stockholders, the employees, and the public, the fruits of the company's progress". The committee, headed by University of Pennsylvania Professor George W. Taylor considers the impact of automatic equipment on steel as critical, will probably take the whole life of the contract, until June 30, 1961, to make its report.

Big noise ahead

The problem of displacement caused by automatic equipment will make a lot of noise in bargaining for the rest of 1960. In the electrical industry five AFL-CIO unions, led by the International Union of Electrical Workers, are concentrating on job security as the number one goal in negotiations with General Electric and Westinghouse. The IUE claims that GE boosted its production by 21 percent from 1955 to 1959, while at the same time cutting employment by 20 percent.

The IUE's approach to solving the problem is tough. Here are some of its demands: supplementary unemployment benefits up to 65 percent of takehome pay of laid off workers; a union-management committee to recommend proper sharing of automation gains; a ban on the company's contracting out construction work while plant union workers are jobless; severance pay; when a factory is shifted, laid-off workers to get first crack at the new jobs, with the company paying moving expenses.

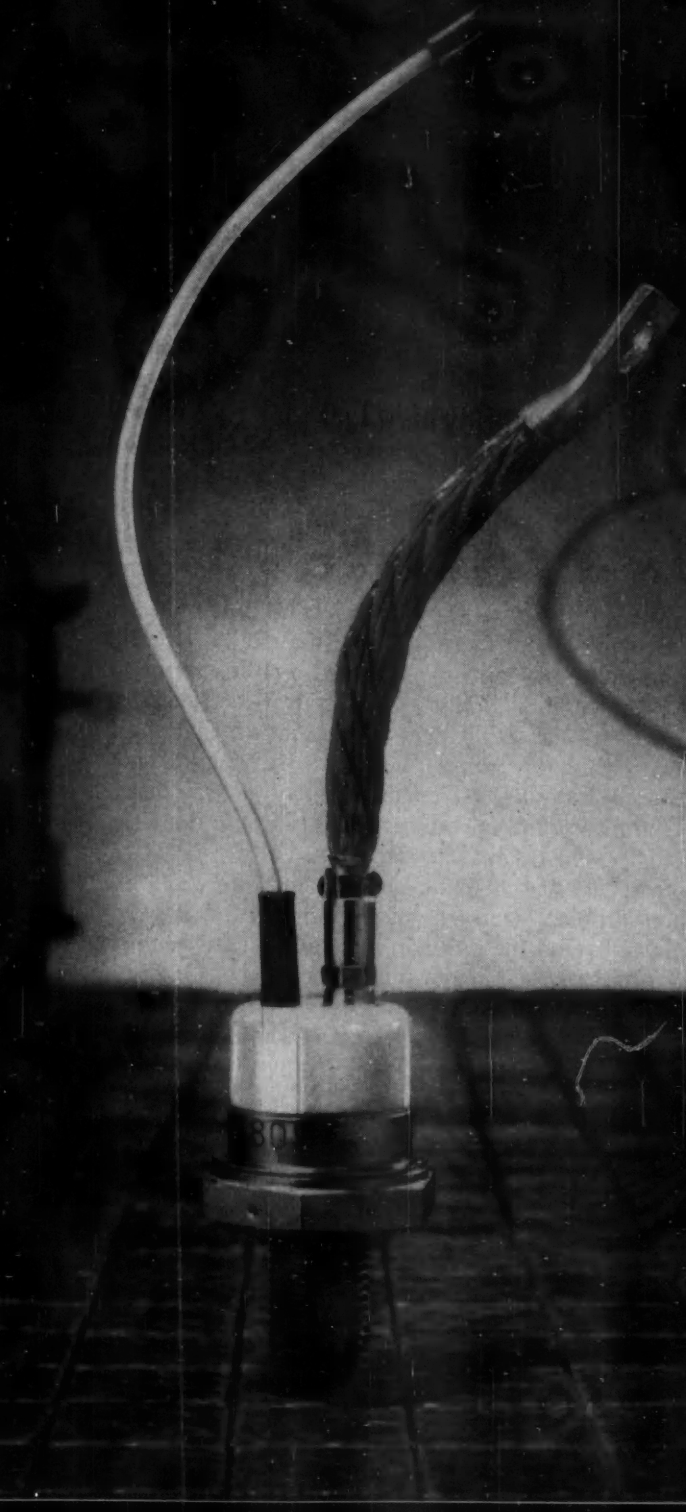
Politics in it

Because the displacement problem has become so serious, it has even shown up in the platforms of both political parties. The 1960 Democratic platform incorporated a section entitled, "Planning for Automation". The Democrats promised "to provide the government leadership necessary to insure that the blessings of automation do not become burdens of unemployment."

The Republicans urged "encouragement of training programs by labor, industry, and government to aid in finding new jobs for persons dislocated by automation".

The prospects of wholesale government intervention into the dislocation problem worry a lot of industry. Congress has already cast an eye on the problem through its joint economic committee, promises to keep reviewing the problem. One thing seems sure: if labor and management do not solve the problem, Congress will step in with legislation whether it is wanted or not.

WESTINGHOUSE ANNOUNCES



50 AMP "ROCK-TOP" TRINISTOR[T] CONTROLLED RECTIFIER

PROVIDES MULTI-FUNCTIONAL CONTROL OF CURRENTS AND VOLTAGES WITH FAST SWITCHING TIME AND RESPONSE RATE

New Westinghouse Trinistor "Rock-Top" construction provides high reliability, low maintenance, and positive protection against arcing at high voltages. Design engineers will find the improved electrical characteristics, listed below, can be used to advantage in a wide range of new control and switching applications.

- Lower Thermal Impedance
- Switching time 600 millimicroseconds
- Efficiencies in excess of 95%
- Simplifies circuitry
- Lower forward drop than thyratrons
- Minimum noise levels
- Parameters ideally suited for high-speed static switch functions
- Peak reverse voltage 60-360 volts

For full information or engineering assistance,
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CIRCLE 131 ON READER SERVICE CARD 131

Automatic Systems in the Plant

- How the pieces fit together
- How far they've penetrated
- How much they earn

WILLIAM E. VANNAH, Control Engineering

It should be possible for a control engineer to expose the structure and flow of a complete business enterprise in such a way that he could make the entire complex completely automatic. He would uncover the qualitative and quantitative interrelationships between machines, people, and the flows of raw materials, cash, energy, information, products, and profits. He would probably construct a vast block diagram to show the relationships of each operation and variable with the others. Given wide freedom to make worthwhile changes, he would devise a master plan to make each function of the enterprise automatic. The technical problems are surmountable. Some military enterprises (missions) are already fully automatic. It should not be impossible to transfer to industrial enterprises the knowledge gained in perfecting the most advanced automatic military missions.

Why is it, then, that industrial automatic systems evolve in piecemeal fashion, rather than as coordinated phases of a massive master plan? In military and industrial systems the control engineer accomplishes the same fundamental result: he makes a system of operations automatic to reduce its uncertainty, to increase the predictability and reliability of its hitting an objective. Industrially the automatic system will, for instance, minimize variability that otherwise requires subsequent inspection, blending, and adjustment of product.

Innovations are piecemeal

The underlying reason for the piecemeal approach in industry is the limited amount of new engineering that an industrial operation will afford. A manufacturing operation is the accumulated product of years of engineering innovation and proof. The structure of the operation is shaped by the preceding technical and economic environment of its industry. Local environments, too, have strong influences. When a new manufacturing unit is on the design board, it is an economic impracticality to start the design from a completely blank piece of paper. Industry can allow up to perhaps 25 percent of the design to be completely new. Therefore the engineer's creativity is channeled into redrawing old sections of the paper and filling in a few new ones at a time.

FIG. 1. Single control loops and unit control operations fit together, piece-by-piece, to create automatic processes, automatic plants, and automatic businesses.

Yet industrial management is becoming aware of the benefits of the "systems approach". It is attracted to the idea of stating a plant's objective in terms of the production of specified products with allowable ranges of characteristics and of then working backward through the entire sequence of operations to optimize the whole. It understands that by integrated attention to every production operation the whole manufacturing process will aim more surely at the objective, with greater reliability, efficiency, and economy. But since management can rarely afford a complete upheaval, it allows innovation where the engineer can convincingly demonstrate the greatest tangible benefit and puts a financial limit on the extent of innovation. This drastically inhibits leaps to complete innovation, but it encourages a steady piecemeal evolution of automatic systems to spread out from the economically most attractive unit operations in the manufacturing sequence. In this atmosphere individual genius conceives and perfects a component tester. Local economics spur the conversion of a batch food proc-

ess to an automatic continuous one. Urgent competitive need to offer metalworking machinery that will make small-run production more economic fosters the development of a numerically controlled machine tool. Preservation of personnel safety simultaneously with integrity of generated power leads designers of steam power systems to mechanize the logic of startup operations.

The pieces fit a common structure

The matching of each system to the peculiar economic and technical environment of its industry and of its location gives it some amount of tailor-made character and some uniqueness. To the casual viewer the wealth of uniqueness may present an overwhelming forest of detail. However, there is a common structure of control engineering into which all of the pieces sensibly fit. It is a hierarchy in which each level ranks according to the scope of variability that it handles. The levels are:

- single-loop control
- unit control operation
- automatic process
- automatic plant
- automatic business

It is appropriate, while explaining a common structure, to demonstrate the extent to which the developments have been applied and what benefits their applications have earned.

The greatest amount of new control work is at the level of the unit machine or unit operation; take it as the central element of the common structure and from it work up to the concept of controlling a complete business and down to the long-accustomed practice of controlling single variables. The unit control operation encompasses the complete control of a key operation in a total production scheme. It integrates all of the single control loops of the operation in response to a program which, in turn, is set off-line by man or by a control computer. Examples of unit control operations in production are numerical machine tool control, the winding of colored thread onto spools for rug-weaving, bread weight adjustment, and blending. Articles in this issue also cover unit control operations in materials handling and product evaluation.

Subsidiary to the unit control operation is a group of single control loops, in each of which one effect-variable is measured and its most influential cause-variable automatically manipulated in response. Single control loops are the slaves of industrial control. Unless continuously directed by unit control operations, they control at points set by human operators. Single loops work by inhibiting interaction within the machine or operation. They tend to eliminate the operation's variability by holding it at one optimum set of conditions. In contrast, the unit control operation puts the variability to work for optimization at all reasonable combinations of the single variables.

Automatic processes are composed of unit control operations. Examples of automatic processes in this issue are a thermal cracking furnace, a hot-strip mill, and generating station startup. They involve the logical coordination and the continuous optimization of unit control operations. All three examples accomplish their decision-making with on-line computers. The degree of innovation is high, well beyond the 25 percent figure given earlier. This is because the computer study that precedes on-line application exposes fruitful changes in process operations, as well as in the unit control operations and single control loops. Systematic study of the process operating patterns, not clearly understood before the computer was programmed with the process model, reveals relatively large opportunities for improvement in operating tactics.

As automatic processes are composed of unit control operations, so automatic plants are composed of automatic processes, and automatic businesses will be made up of automatic plants. Two articles describe the application of data transmission equip-

Industrial automatic systems earn these benefits. Check them off to establish tangible economic justifications for proposed systems.

increased production	
more efficient scheduling of loads to machines	
improved operating routines	
more economic small production runs	
reduction in standby storage and blending capacity	
savings in raw materials	
reduction in reject rate	
minimized recycling or reprocessing	
reduced labor costs when personnel are reassigned	

Check these intangible benefits to establish additional justification.

reduced downtime and delays	
streamlined ordering and inventorying	
machine-printed comparisons of shoploads and time standards	
component reliability data printed for designers	
machine-computed incentives, yields, and schedules	
briefer instruction of operators	
increased safety	
assurance that products meet legal requirements	
prevention of tool collisions	

ment and data processors to the monitoring and control of production processes within plants. The article immediately following this introduction discusses work leading to an automatic business.

Throughout the case histories, equipment surveys, and status reports of industrial automatic systems run recurring justifications for making operations more automatic. Over all is reduction in the effect of variability on the manufactured product. Variations in raw materials, in energy and power, and in functioning of the manufacturing machinery and equipment are constrained or coordinated automatically. "How much did it pay?" is the question that was answered in most cases. If the answer had come forth in every case, we would then know how much each automatic system brought into the till, as well as how much it took out. All too often, however, a limit on the percentage of capital investment that could go to automatic systems has forced the engineer to concentrate on how much he could buy, regardless of how much an advanced control system might pay. As a result the industrial control engineer is an expert on costs of control products. From memory he can quote the price sheets of control manufacturers. He has yet to develop a comparable ability to estimate payoff. He recognizes the factors that definitely produce economic gains and in a few cases he has assigned dollar values to them. An important factor in selecting articles for this issue was the question of whether they stated justification in concrete terms. The first checklist catalogs solid justifications that yield handsome payouts.

Other reported improvements are justifiable but their values are less clear-cut. Reduction of downtime and delays unquestionably has value because time is the base of wages, equipment funding charges, storage charges, and product delivery penalties. They go on with time, whether the machinery or operation is running or not. The authors imply that time is money, but how much, they do not report. What values may one assign to the "intangible" benefits enumerated in the second checklist?

Incongruities

Opportunities for the control engineer are expanding along two dimensions. First, there is the tendency of automatic systems to encompass more and more of the elements of business and industry, as this issue demonstrates. Second, the ideas and advantages of single loop control and unit control operations are spreading out to industries that have been technologically more backward than the major manufacturing industries. Examples of the second expanding dimension are the cleaning industry, mining, sawmills, baking, textile spinning, concrete-block making, and municipal plants. Articles in the issue demonstrate this sideways penetration.

The first expansion, the increasing dominion of control systems over operations and business, presents a challenge, for the control engineer must acquire new knowledge. Challenges are opportunities or dangers, depending on the degree of the individual engineer's conservatism or reluctance to face new tasks. Industrial management has been surprised to learn that capable instrument people and some control engineers with a wealth of practical experience have shown more fear of increasingly automatic systems than have operators who may have a more compelling reason for fear—job displacement. (Industry's Pulse, page 125, reports on the job displacement problem, the issues it raises this year, and some solutions that have already evolved.) Displacement of customary jobs and outmoding of engineering knowledge through penetration of control beyond the unit control operation require retooling of skills. Examples in the issue demonstrate that operators may adapt to more highly automatic machines and processes with relatively brief training. The industrial control engineer, on the other hand, must acquire a great deal of new knowledge to adequately adapt to the new engineering tasks. He must learn, for instance, the principles of logic switching, dynamic response, computer technology, and at least a smattering of statistics. The opportunity is here for him to build a more creative job on the foundation of his thorough knowledge of single control loops and the operations to which he has applied them. He has a headstart on newcomers. The question is whether he, standing at the interface between the simple and complex, will be able to capitalize on his advantage.

In similar vein, the maintenance man is faced with a more complex and responsible job. He must learn about the functions and equipment of advanced control. He must become familiar with the use of test equipment that he has seen in development labs but not in plants.

FIG. 2. Operator will have to learn few new skills, control engineer and maintenance man a great variety.

Using Corporate Models for Business Control

Business management for maximum profitability requires control of more than physical processes and manufacturing facilities. What is needed is more up-to-date and more accurate information about such things as industry sales, raw materials sources, transportation alternatives, shop order status, and in-process inventory. Also needed are better ways to handle the staggering volume of paperwork, so that management can quickly formulate the best operating strategy in today's competitive economy. In the first article in this section, a CtE editor considers how mathematical corporate models, mechanized on computers, will begin to provide critical management decision information. Article two tells how a general purpose computer keeps track of thousands of orders for fabricated parts, lowering costs and smoothing production. And finally in number three another CtE editor surveys an exploding field; commercially-available systems for automatic production monitoring and control on the factory floor.

HARRY R. KARP, Control Engineering

Maximizing corporate profits remains the prime objective of industrial organizations. Recognizing the shortcomings of the present accountant-oriented approach to dollar optimization, the questions occupying the thoughts of long-range planners are: Can the manifold functions and vagaries involved in optimizing the profit of an extensive industrial organization be reduced to realistic equations forming a corporate mathematical model? Can the corporate model be stored and processed by a digital computer to yield the optimum course of action to be taken to meet a company's strategic objectives? Apparently the answer to both questions is Yes, in view of the study and effort now being put into this aspect of business system control.

Considerable effort and money have already been expended by many companies to obtain maximum profits by analyzing and optimizing some small, local portion of their operations. Invariably such optimization requires a digital computer to manipulate the many thousands of bits of data. Whether optimization is by open or closed-loop control, the computer has stored within it a well formulated mathematical model of the local controlled unit, plant, or operation. Evidence and experience gained so far indicate that valid mathematical models can be derived and that digital computers can solve the problem reliably. Ample precedent exists for the extension of optimization to the maximizing of profits of larger portions of a company's far-flung operation.

What constitutes a corporate model?

The main difference between local and corporate optimization is the type of information included in a realistic mathematical model. In the local optimization control installations announced so far, the computer-stored mathematical model takes into account a relatively limited set of essentially technological conditions. Corporate models, however, will encompass a greater sphere of company activity. For one thing, corporate models may include a description of similar activities of similar plants geographically distant from each other, thus giving management an opportunity to optimize interplant operations. Or the model may represent greater portions of operations at one locale.

In the corporate model the phenomena included may be extended to more than technological conditions. Thus, within the framework of a multitude of interrelated, interacting variables affecting corporate profits, four fundamental equations may prove useful in developing corporate models: definitional, technological, behavioral, and institutional. Ex-

FOUR BASIC EQUATIONS FOR DEVELOPING CORPORATE MODELS

Equation	Phenomena analyzed	Inputs required to derive equation	Accuracy or stability of equation as an estimator	Major use of equation
Definitional	Exact stipulated interrelations (i.e., exact by definition)	None, represent exact definitions. Knowledge of the interrelation between the variables.	Accurate by definition, exact by definition	To develop precise interrelations between variables
Technological	The results of interactions of an essentially technological or physical process	Historical data describing the inputs and outputs of the technological process. Knowledge of the dynamics of the process	Normally accurate and highly stable as long as the process has been accurately described and is not subject to sharp change	To forecast or project the results of a technological process in terms of the inputs required to yield a desired output or, conversely, the output that can be expected from a given combination of inputs
Behavioral	Human behavior patterns: the response of the company's customers, workers, and competitors, etc. to a given stimuli	Historical data describing the behavior of a given sector of the population to a given measurable stimuli. Knowledge of the behavior pattern	Depends on the persistence and stability of the behavior pattern. Subject to random "shocks" since human behavior patterns cannot be perfectly reduced to mathematical equations	To forecast or project the results of a change in some given independent variable (or set of independent variables) on the behavior (i.e., purchasing, expenditure or investment, etc.) pattern of a given human population
Institutional	Operating or marketing constraints introduced by either the company's own policies or the policies of government, the banking system, the industry, etc.	Historical or projected values of the institutional constraint parameters. Knowledge of the institutional structure	Accurate by definition as long as policy or institutional factors do not change. Subject to error if the projected policies change	To develop an objective, explicit estimate of the impact of a given company or external policy on the company's operations and to render explicit all of the purely institutional constraints which limit courses of action open to company

Copyright: 1960, ANA (Ref. 1)

planations of these phenomena are given in the table (Ref. 1). Combinations of the four basic equations permit corporate description by 15 equation types.

R. S. Weinberg of International Business Machines Corp., originator of this table, states that the purpose of the mathematical model is to render the profit maximization problem explicit. "While mathematical models will never yield panaceas or a set of 'cure-all' formulas, they provide a logical means for utilizing *all* available information to develop more realistic and efficient marketing plans."

Essentially, then, the corporate model will be a formulation of the company's strategy in optimizing its profit while operating in a complex environment. The model will take into account the effects of economic, internal, competitive, and institutional environments, thus relating the company's operational strategy to such factors as total industry sales, general economic activity, share of market, production capacity, relations between sales, taxes and profit, and action-limiting policies.

Formulating a realistic corporate model

Practically speaking, of course, a great amount of human discretion is required to formulate a realistic model, lest the needed calculations strangulate the computer. The number of possible optimizing calculations is k^n, where k is the number of values applied to each of n inputs. Thus, if k equals 4 and n equals 10 (a fairly simple situation) the number of "brute-force" calculations to find the optimum is over 1 million. While it is within the capability of a large digital computer to calculate the 1 million answers in a relatively short time, adding just a few more inputs renders the computing problem horrendous and the optimizing project self-defeating.

In the initial formulation of the model, management specialists will prepare a list of variables (or inputs) which may in a gross sense have some effect on profits. Suppose the list includes 100 inputs. Management's subjective experience regarding the noninfluence of some of these variables permits the list to be reduced to, say, 50 variables. But even this number may be too great. Then the remaining 50 variables may be subjected to a sensitivity analysis to determine, say, 23 critical variables, a small enough number to be handled by the computer. The sensitivity analysis may take the form of a factorial or fractional factorial design (Ref. 2). The analysis may indicate that some variables seemingly important in determining profit may in fact not be significant over a range of values and therefore may be replaced by a constant. The sensitivity analysis serves another useful purpose, that of determining the impact of the uncertainty or error of those critical inputs like sales forecasts which are estimated values.

Where corporate-model control stands

While it is fairly easy to visualize the broad, general ideas and significance of corporate-model control, an important factor is the seriousness with which this concept is being approached and applied now. Some work is being done along this line, albeit under the guise of such other scientific dis-

ciplines as operations research, computer simulation and optimization, and market research and planning. One can reasonably assume that work is more advanced than is indicated in the published reports. A few examples, based on announced efforts, will indicate the present status.

Socony Mobil Oil Co.'s Dr. J. Aronofsky described some of the difficult and perplexing problems confronting large integrated oil companies in scheduling their operations (Ref. 3). Such operations can be represented by two flow models: 1) a fluid flow model that portrays transportation of crude oil from underground reservoirs to refineries, the crude's movement and conversion to an array of products within the refineries, and distribution of refined products to the consumer and 2) a cash flow model that represents, at each significant operating phase in the fluid flow journey, whether profit is being generated or absorbed.

"The contention is made that it will be feasible to construct a mathematical model that will observe all fluid flow requirements (or commitments) and, at the same time, will keep track of all cash flow both into and out of the till. Furthermore, the contention is made that it will be technically feasible to solve this mathematical model (on an electronic computer) when some specific data are fed into the computer. Once the computer calculation has been completed, there will appear in report form, by means of a high speed printer, some answers that could very well become the operating plan of the corporation. It will spell out in detail: what crudes should go to what refinery, the throughput and product yields at each refinery, the complete allocation of product distribution all the way to the consumer, and a summation of estimated operating budgets broken down for each important facility. . . . A frequent comparison of actual versus plan would be desirable in order to update and improve the model itself, and to provide a yardstick for judging the efficiency of each operating facility."

Day-to-day scheduling

D. S. McArthur et al reported the development and day-to-day use of a mathematical model that represents one part of the over-all interplant corporate model (Ref. 4). "Studies have been carried out by affiliated companies of the Standard Oil Company (N. J.) which have produced mathematical tools to assist in solving problems concerning marine transportation and terminal tankage. . . . [One] operations research study had as its purpose the minimizing of all terminal and transportation costs involved in tanker movement of refined products from refineries to terminals. . . ."

The operation involved 20-25 tankers moving products from one supply source to 14 terminals and to 15-25 major bulk cargo customers. A terminal handles 5-15 products, and each ship contains compartments for carrying 1-10 different products. "The scheduling decisions to be made were what products and how much of each product to load on a ship and the terminal or terminals to which it should be sent. . . . Briefly, the method looks ahead 14 days and considers each ship in sequence as it becomes available for loading. It then evaluates each ship for possible assignment to each terminal and calculates a minimum cost cargo for each of the possible assignments. Then, using the cost for sending any ship to any terminal, it considers the ships in sequence through a series of five-day look-ahead periods. It then develops a minimum cost ship assignment schedule for each of the five-day periods, considering the assignment of ships in previous five-day periods."

Interplant production allocation

More limited but still valuable investigations of interplant control can be studied with analog computers. The DuPont Co.'s Munson and Electronic Associates, Inc.'s Rubin, in a paper on optimization by random search, described the application of the analog computer to a production allocation problem between two plants (Ref. 5). Standard electronic analog computer equipment is used to determine optimum operating conditions for many randomly chosen combinations of independent parameters. Gaussian noise sources generate values of the independent parameters, and sample-hold circuits store those values which give the best value of the optimization criterion.

"Two plants make several of the same products. Each of these products has a sales demand and is used as a raw material for one or more other processes. Because of geographical location, age of equipment, availability of labor and other similar factors, the costs of production at the two plants differ for each product. The problem was to determine, for any particular set of sales demands, the split of production between the two plants which would minimize over-all cost."

If interrogation for optimization occurs perhaps once a month, it will probably be feasible to convert the analog model to its equivalent digital program (possibly smoothing the less significant nonlinearities to simplify the digital program) and to assign the problem as one more task for a digital computer.

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Computer Keeps Tabs on Work in Process

The precise location and status of each of 45,000 orders for fabricated parts is continuously followed by an IBM 305 RAMAC computer in a new order locating system recently installed at Lockheed (Marietta). Reassigned expediters and file clerks have helped to lower costs by $3,500 a month for a system that's better and faster

E. W. CANNON, Lockheed Aircraft Corp.

Lockheed's Marietta, Ga., plant is the largest aircraft installation under one roof in the country. Over 10,000 employees are kept busy producing the C-130 Hercules, a prop-jet cargo-personnel transport, and the JetStar, a pure jet utility transport. Marietta is also converting B-47 jets into pilotless aircraft for U. S. defense testing. This tremendous operation has as many as 45,000 parts in stock or in various stages of fabrication or assembly at the same time. Thus it is not unusual for 1,500 to 2,000 inquiries to be made about the production status of individual orders in a single two-shift day.

The task of keeping track of all of the 45,000 fabricated-part orders has recently been given to an IBM 305 RAMAC computer, which stores the necessary information about each of the parts on one of its 50 magnetic disks. The double density, 10 million character storage capacity of the present disc file can actually handle over 90,000 part orders if necessary. Because of RAMAC's speed and the fact that only a fraction of the part orders in process moves during short intervals of time, the RAMAC file is actually updated hourly, even while producing nearly instantaneous answers to the 100 or more inquiries that are made each hour. The result is that the part locating job is now being done faster and better than ever before. And the total operating cost of the system is $3,500 a month less.

The old system . . .

With the former job progress system, a request for the status of an order sent an expediter scurrying to a manually maintained locator file for the data and then hustling through the plant to try to catch up with the part. Eight clerks were required to keep the locator file within several hours of the actual order locations, and valuable time was lost in the resultant station to station searching by the expediters. Also, it would have been prohibitively costly to generate any kind of summary of shop loading from the locator file data.

. . . and the new

The new computer system has done away with the locator file and permitted reassignment of its eight clerks plus 12 expediters. In the new system IBM transceivers which read, transmit, and reproduce punched cards are located strategically in the plant to speed remote inquiries. One transceiver is located near the RAMAC 305 (see Figure 1); three others are in the JetStar stock area (see Figure 2), the subassembly stock area, and the C-130 open stock control area. There are also five "hot" telephone lines feeding into the Data Processing Dept. which are used for urgent or short inquiries.

The usual inquiry is punched into a card at remote stations beside the transceivers, transmitted to Data Processing and fed into the computer, Figure 3, which punches out the answer. The answer is sent by transceiver back to the remote station which punches out a card for the expediter. The answer to the query is printed along the top of the card in a code which the expediter can read (see Figure 4).

When an expediter phones in, the operator in the Data Processing Dept. cuts a punched card and feeds it into the computer, as shown in Figure 1. The answer, received in seconds via the computer's console typewriter, is passed on by telephone.

In addition, an IBM 381 remote inquiry station has been set up in the Production Control Div. where nearly all shop orders for fabricated parts are released to production. This inquiry station enables the Production Control staff to query the computer directly, via keyboard, concerning the status of a particular order. The answer is automatically typed out at the inquiry station, see Figure 4. This procedure eliminates delays in waiting for a clear line and the possibility of errors from misreading or incorrectly copying an answer relayed by phone.

FIG. 1. Data Processing Dept. operator punches card for urgent inquiry. RAMAC computer behind him will read card and type out order status information in seconds. Operator will then read computer's answer to expediter. Transceiver in foreground is used for most inquiries.

FIG. 2. Usual inquiry is punched into cards at remote transceivers such as this one in stock area and transmitted to RAMAC. Output card from computer is then reproduced at remote transceiver with coded answer printed along top (see Figure 4).

FIG. 3. IBM 305 RAMAC computer is queried by punched cards as shown, or by keyboard, which is duplicated in Production Control Dept. Computer output is via punched cards or the typewriter at right, which is also duplicated in Production Control.

When a shop order is written, Lockheed's IBM 705 computer produces origin cards and traveler cards for the RAMAC 305 work progress system. A few shop orders are also prepared manually in Production Control and subsequently keypunched.

The origin cards are fed into the RAMAC 305, which stores the necessary information on its memory disks. Usually a card will indicate a part number already ordered several times before, with work in process. If there is a part number record already stored, the computer creates an additional reference number portion to the over-all part number record. Thus if several orders are in process, it is possible to expedite delivery on a portion of an order by splitting it into two or more new orders. If no order had been previously stored for a particular part number, its reference number, completion date, quantity ordered, activity date, cost center to which the order is sent, and operation number are set up in the 305 RAMAC.

The traveler cards accompany the order from station to station. When an operation in a given cost center is completed, the traveler card is taken to a booth along the assembly line where an operator on an IBM 26 printing card punch produces a movement card indicating part number, reference number, quantity being moved, the completing cost center, the next cost center, and the operation number just completed. The traveler card is then returned to the order, which moves on to the next cost center.

Every hour the movement cards are collected from all the booths and processed through the RAMAC 305, updating the stored information. As a result the stored records are always precise to within an hour of showing where an order is being processed at a given time. The RAMAC system also gives a system of checks and balances based on the operation numbers used. The computer will reject any input with a lower operation number than the number on record for the order. For example, if normal movement from one station to the next is interrupted, a zero operation number is punched into the movement card and, before the computer processes it as input, the card is automatically checked for acceptability.

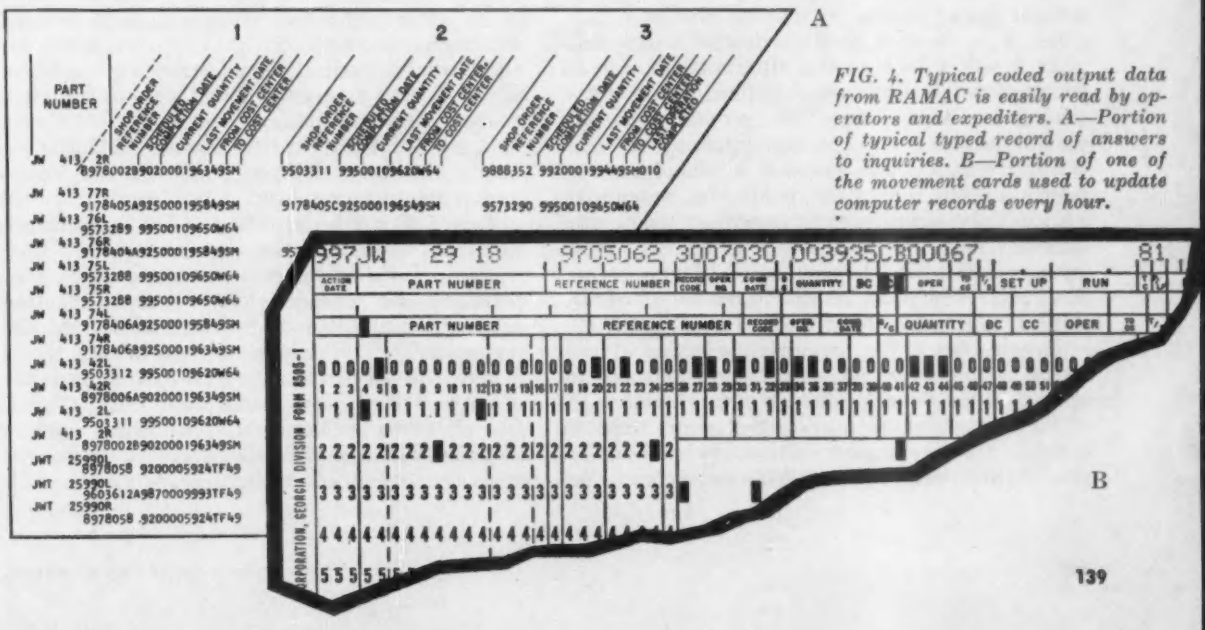

FIG. 4. Typical coded output data from RAMAC is easily read by operators and expediters. A—Portion of typical typed record of answers to inquiries. B—Portion of one of the movement cards used to update computer records every hour.

Controlling Production Paperwork

The objective of automatic control of production paperwork is to gather and summarize information about production quickly enough and clearly enough so that management can take steps to optimize the operation. Three types of equipment are available to do this: a monitoring system that reports when a production machine is running, a data accumulation system that converts production data from the shop into computer format at a central processing station, and a special purpose computer system that performs computation on the data as they are gathered.

LEWIS H. YOUNG, Control Engineering

Plagued with too high machine downtime, a German plastics company installed an automatic production monitoring system to watch its 80 machines, reported startling improvement after just three months of operation (see Figure 1):

- Unnecessary personnel delays (operators not at the proper machine at the proper time) were cut from 2,140 min per shift to 90 min.
- Downtime resulting from no material at machine dropped from 753 min per shift to 100 min.
- Downtime caused by machine or tool breakdown decreased from 3,915 min per shift to 100 min.
- Delays due to tool changes were cut from 2,921 min per shift to 990 min.
- Delays caused by a machine having no work were reduced from 933 min per shift to 180 min.

In a U.S. stamping plant, production increased 25 percent within three months after installation of an automatic production control system. A screw machine products company jumped production 22 percent by installing a monitoring system.

These examples indicate what is behind management's sudden interest in production monitoring and control systems. Properly used, automatic production control can lead to big savings, and these savings occur where they add up quickly: a reduction of direct labor, an increase in the output of machinery, and better use of materials.

The objective of the automatic production control system is to gather data about production and to summarize them quickly enough and clearly enough so that management can take the proper steps to optimize the company's operation. Behind the design of the systems now available is this idea: the best place to get the input information for production control is as close to the machine doing the producing as possible.

To do this job, three families of equipment have evolved, are now offered commercially.

Type 1. Monitoring systems which merely report and/or record when a production machine is running. They also are a communication link connecting a supervisor at a central control point with the operator at the machine and other key work areas such as the maintenance department, stock room, and tool room. This type of equipment is illustrated by the Telecontrol System built by Hancock Industries and Productograph, a German designed system introduced into the United States this month by Farrington Mfg. Co.

Type 2. Punched card data accumulation systems. Machine operators place punched cards into devices located on the production floor to send production or inventory information to a central point or direct to a computer for processing. Suppliers of such systems include: General Time's Stromberg Time Div. which makes Transacter, IBM with its 357 data collection system, Friden Corp. building Collectadata, and RCA with its EDGE system which is still in the developmental stage and will not be announced until later this year.

Type 3. Computer systems for data accumulation in which the compilation requires so much computation that it is necessary to place a digital computer on the production floor. Major examples occur in the process industry—particularly steel rolling, utility industry, and petroleum-chemical manufacturing. Most makers of process control computers claim their equipment can do this work. General Electric (with its 302 data accumulator) and Airborne Instruments make special purpose computers especially for this job in the steel industry.

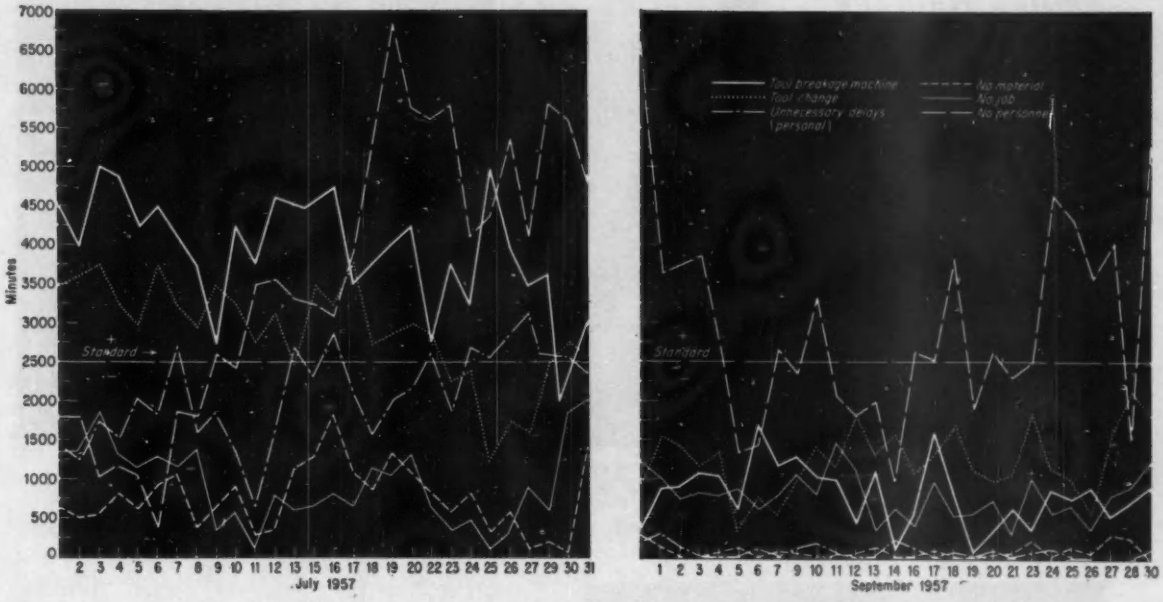

FIG. 1. Production monitoring systems cut downtime sharply. Here is what happened at a German plastics factory when it installed Productograph in August. July figures were compiled before installation; September figures, after installation.

Hancock's Telecontrol

Already installed in nine different industries—plastics processing, printing, leather tanning, automotive parts, specialty hardware, die casting, industrial machinery manufacturing, major household appliances, and small household appliances, Telecontrol is a monitoring system that attacks unnecessary downtime. It is an electromechanical system built by Hancock Industries at Jackson, Mich. The system is composed of five main parts: a sensing device mounted on the machine to count the parts produced; a machine control box with alarm lights, a run-alarm switch, and a telephone jack; a central control panel with alarm lights and electromechanical piece and time counters; a key operations recorder that can chart what's happening at 40 stations on a single strip of paper; and an in-plant public address system.

Here is how A. O. Smith, an automotive parts supplier, has used the system. As soon as a press operator (the company has connected 53 presses to the Telecontrol system) runs into trouble such as a broken fixture, he switches the run-alarm toggle on the machine control box located right on the press, starting a red light blinking and a warning beep in the central control room. Noting the number of the machine alarmed, the Telecontrol dispatcher announces the number of the machine in trouble over the loudspeaker so the foreman responsible for that press is immediately advised that one of his machines is down. The foreman goes to the press, plugs a telephone handset into the machine control box to advise the dispatcher what happened and what to do to correct it (in this case, call the maintenance department). While all this is happening, a counter in the control room is keeping a record of the amount of downtime. With the monitoring system machine downtime for a simple breakdown was cut from 30 to 15 min.

From an equipment standpoint the hardware is relatively simple. The entire Telecontrol system is timed by a master clock that starts the system on command, turning on green ready signals on the control board and at the machine control box. On the machine the green light tells the operator that the equipment is operative. The sensing device used varies depending on the item being counted. It could be a limit switch, a photocell, a mechanical gate, or some other device such as a pressure switch. As each part is produced by the machine, a piece count is transmitted by the sensor through the machine control box to the control panel in the central control room.

On the control panel the Telecontrol dispatcher can see a light for each machine—green if the machine is operating, blinking red if it is down but not reported, red if it is down. He can also read four mechanical counters for each machine: one counts production time, a second totals downtime, a third adds up completed pieces, and the fourth indicates the balance of the particular job to be produced. When the last counter indicates zero, the green operating lights on the panel and at the machine start blinking, advising both the dispatcher and the operator that the job is completed. This is important in industries such as printing and screw machine products which have overrun problems.

Also displayed on the control panel for each machine are such auxiliary bits of information as the

FIG. 2. From this control box on a production machine an operator can communicate with and transmit information to . . .

. . . this central control where a single dispatcher watches two panels, each handling 20 machines, and monitoring key readouts.

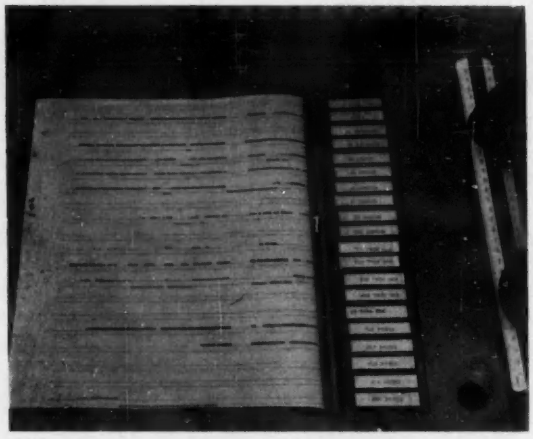

FIG. 3. Permanent record of cause of downtime is reproduced on this recorder.

part number being made on a machine, the customer's name, and the machine operator's name and number. And it is possible to count the output of each shift separately in a multishift operation.

The only permanent record from the Telecontrol system is maintained on a device called the key operations recorder which can chart the activity of up to 40 machines. Its record for each machine is simple: whether the machine was running or not.

Cost of a Telecontrol installation varies between $350 and $550 per machine, depending on voice paging requirements, the kind of sensing devices required, and in-plant wiring requirements. To date every installation has paid for itself within one year. One user claims to have paid for the installation in 30 days from savings in downtime.

Productograph

A somewhat similar approach has been refined by the Josef Mayr Co. to provide more detailed information about the production process. Available in Europe for several years, Productograph is just now being made commercially available in the United States and there are already two installations: one at a screw machine parts maker and another in a stamping plant. A variety of potential users are interested including an airline for its maintenance shop. In Germany, installations have been made in a home radio plant, a plastics plant, a rubber processing plant, a textile plant, and some chemical plants.

Productograph offers a greater variety of sensing devices for counting the fruits of production—14 different techniques. Some of the unusual ones: a photoelectric cell counts objects on conveyor belts or packaging machines; flowmeters are available to measure air, gas, oil, power, or water; a meter transmitter can count length units; a microphone relay responds to noise and vibration, can be used to count parts or record operating time; a voltage relay records the operating time of machine tools, looms, and similar equipment; and gear transmitter attachments are flanged to a machine shaft or connected by a chain to measure length or number of revolutions.

Probably the main difference between Productograph and Telecontrol is the former's ability to identify the cause of downtime. With a Productograph installation, when an operator signals the dispatcher that a machine is down, he also signals the cause of the downtime by pushing one of five buttons on the machine control box. A company can set up to detail downtime by any five causes that occur most often in its operations, for example: no material, machine breakdown, tool change, setup.

Because it supplies additional information, the control panel is more complicated. For example, each machine has six time counters: one for production time when the machine is running, five for downtime—one for each cause of delay. By looking at the six counters, a supervisor can tell how much each machine has run, and how much time it has lost for each of the five reasons for delay.

Production quantity counting is also more complicated. The number of units produced by each machine is shown on a mechanical counter and on a linear counting scale, which not only displays how many units were produced by the machine but also how many are to be produced for the order. As production proceeds, a blue film tape moves across a quantity scale from left to right. At the start of an order, the dispatcher puts in the total required by moving a yellow film from the right end of the scale to the quantity. When the blue film reaches the yellow film, the order is completed. With its row of linear scales, the control panel looks like a huge Gant chart, but the linear scale of Productograph is operated automatically.

A paper recorder charts the production time and downtime of each machine, the recorder track depending on what is being recorded. For example, production time might be charted as a thick black line; downtime caused by machine trouble might be recorded as a series of closely drawn thin single lines; downtime caused by a material shortage might appear as a series of thick black lines.

Productograph also offers as an accessory an integrating counter which will sum up all the time lost by all machines for the same reason. With this accessory, management can tell at a glance how much time the entire operation has lost to machine breakdowns, for example, or material shortages or setup.

One other quick reference feature of the system is a lamp panel with five lamps for each machine. With a glance the dispatcher can tell what machines are down and the reason each is not running.

With the addition of some computing circuitry, Productograph can calculate the machine operator's pay. A typical leasing cost: about $1,000 per month for a 20-machine system.

Data accumulation systems

Both Telecontrol and Productograph allow management to exert minute-to-minute control of production machines. But they have a limitation, particularly for the company which has a computer for business data processing: the outputs of the monitoring system are not compatible with any general purpose computer. To solve this problem, new data accumulation systems have been developed to record production data at the machine and to transmit them to a central point where they are put into computer format for further data processing.

This type of system works best in production control and inventory management. It seems particularly suitable for job shop manufacturing in which a complex product is built in many operations or of many parts.

Most companies control raw material inventory and the stock of finished products reasonably well. Where they fall down is the control of work-in-process inventory. It is in this application that the data accumulation system contributes to management efficiency. With such a system, management can know quickly where every shop order is, how much has been invested in the order to that point, and whether the job is on schedule or not.

Transacter

Typical of the systems to do this job is Transacter, especially built by the Stromberg Time Div. of General Time Corp. for industrial production and inventory control. A machine operator or stockroom clerk puts information prepunched on cards into a transaction transmitter located close to his work station. The data are then carried over wires to a compiler which converts them to computer format on punched tape and adds such information as date, time, and shift. One compiler is connected to a number of satellite transmitters.

A key feature of the Stromberg system is the wide use of prepunched cards. Since the most expensive part of a punched card operation is preparation of the source documents, Stromberg has designed the system to use prepunched cards, which can be turned out automatically.

Here is how the system would work in production control. When an operator on a machine tool, for example, finishes a shop order, he transmits this information to the compiler. To do this, he might put as many as three punched cards into the transaction transmitter. First he might put in a 15-column plastic punched card which would identify himself, his clock number, his station, and his wage rate. Next a 22-column card might be inserted to identify the machine on which the work was performed, its standard time, depreciation rate, etc. Finally, an 80-column card, traveling with the job, would identify the job, the order, the cost and other essential information. In addition, the operator can dial in some information such as the quantity of items produced on this particular job. After the cards have been inserted and the quantities dialed in, he hits a transaction bar to transmit all the data simultaneously.

Since he previously had transmitted the arrival of the order at his machine, the exact times of the start and stop of the operation are recorded remotely. It he were to run into trouble such as a machine breakdown during the job, he would advise the compiler of this by placing appropriate prepunched cards into the transaction transmitter. By using a different prepunched card for each cause of trouble, he can help classify the reason for downtime. The device is also used as a time clock by operators to punch in and out when they report for work and leave.

Here is how Transacter might work on an inventory control problem. When an order is to be placed, a punched card is prepared containing essential information: supplier, part number and description, quantity, size, color, etc. The same punched card serves as a requisition, request for quotation, purchase order, receiving report, incoming inspection, and final receipt in stockroom. Transmitters in

purchasing, the receiving room, the inspection area, and the stockroom keep information about the order up to date.

When a specific Transacter system is planned, a code is set up to identify what is being reported and to specify what items are required to report that information. For example, for an operator to check in, the system might require just one 15-column prepunched card, placed in the far left card slot. To report the arrival of an order at a station might require two punched cards; to report the completion of an order might require three punched cards and a quantity dialed in. To advise the compiler what information is about to be sent, the operator turns a coding dial to the proper position. If he sets the dial to report a completion of a job and fails to dial in the quantity, for example, the system will not transmit; instead, it will show him a warning red light indicating that the transaction was reported incorrectly and was not transmitted.

Information on each line of the card is carried to the compiler over a separate wire pair. In all, the Transacter system needs 29 wire pairs; 12 carry information punched into the cards, one for each line on the card; other wire pairs carry such information as the timing signal, the Transacter code (which determines what is being reported) an audio line for servicing so a maintenance man at the transmitter can talk to a maintenance man at the compiler, and a scanning signal that keeps one transmitter from tying up the system if an error is detected.

Information is transmitted as a 12-pulse IBM code. The compiler converts it to 5, 6, 7, or 8-channel paper tape code. In addition, the compiler performs the necessary logic to decide whether the transmission was carried out correctly, to check the length of the message to insure accuracy of transmission, and to measure the strength of each pulse so that a warning can be sent if a pulse too weak for reading is received. The error checking features make Transacter's performance practically perfect. During a typical month's operation at its pilot installation, the Transacter compiler received and punched 1,015,960 characters with just one in error.

As of July, seven installations of Transacter have been made—two in aircraft companies, two in plants of makers of electronic systems, one in a ball bearing factory, one in a government job shop, and one in an airline maintenance and overhaul station; 14 more will be in by November. The system is leased, and a typical monthly rental is $350 for the compiler and from $47 to $74 per transmitter. Cable installations cost about $1 per foot.

IBM 357 DATA ACCUMULATION SYSTEM

FIG. 4. Worker inserts two 80-column punched cards into card reader, then punches in variable information on keyboard to send up-to-date production information from the shop to . . .

. . . a receiver in the data processing department where the information is put on punched cards.

IBM 357 System

Prepunched cards are also the backbone of the IBM 357 Data Collection System. A punched card to punched card system, the 357 requires that a machine operator put two 80-column punched cards into an input station located close to his machine to pass production data to the data processing department. One card identifies the operator with his employee number, job classification, pay rate, etc.; the other is a traveler card identifying the job.

One big difference in the IBM system, compared to the others like it, is the relatively complex 12-column keyboard by which a man on the production floor can send in auxiliary information. An instruction code on the punched card automatically shifts transmission from the card to the keyboard. Actual readout from the 12 columns is controlled by the digits punched in the transaction cards that follow the instruction codes. The keyboard columns can be read out in any desired order by using a code that corresponds to the keyboard columns. Digit keys in each column are numbered from 9 to 1. There are no zero keys; zeros are read out automatically if no digit key is depressed.

A typical 20-station system (10 stations with keyboard and 10 with just a card input station) rents for about $1,000 per month. It would include the

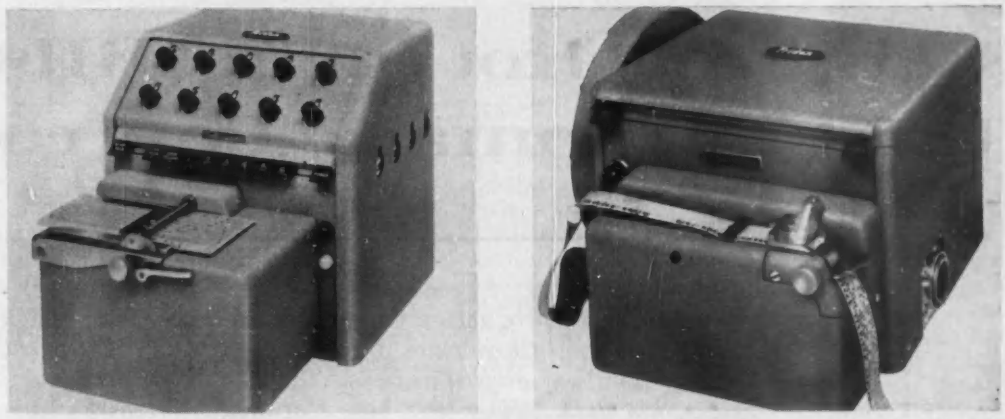

FIG. 5. From transmitter in the shop . . . to punched tape receiver in the data processing department.

20 input stations, an input control unit that sequences data transmissions as they are initiated from the various input stations, the central output station which reproduces the data at distances as much as one mile away, and an automatic clock which inserts time into punched card reports.

To date the IBM 357 has been installed in such diversified industries as an aircraft company, an appliance manufacturer, a public utility, an electronic systems builder, and a general fabrication plant.

Collectadata

A somewhat similar system has been marketed by the Friden Corp. under the name Collectadata. In this, however, only a traveler punched card is used, either a conventional tab card or an edge punched card. Variable information can be inserted into the system by 12 dials on the transmitter, which is located in the work area.

With the Collectadata system when a production order for a job is prepared, the punched card traveler is also created so that it contains such information as order number, part number, and quantity. When the job arrives at a work station, the machine operator inserts the card into the Collectadata transmitter which reads it and sends the information thereon by cable to a data collecting receiver where it is reproduced on punched tape. The tape can then be processed further by other equipment, for example: a tape-to-card converter, a computer, etc.

In one application at the Northrop Corp., 97 transmitters have been connected to 20 receiving stations to control production throughout the company's 27 manufacturing shops. Data collected on 8-hole punched tape is forwarded to a computer center where they are first transferred to punched cards and then to magnetic tape. By processing the tapes at night, the company has a complete record of work-in-progress every morning.

Computer data accumulation

To gather production data in a continuous process requires a much more complex system than any of those previously described, a system such as the Data Accumulator announced this summer by Airborne Instruments Laboratory, a division of Cutler-Hammer, Inc. Primary application of this system so far has been in the steel industry where it looks promising in such processes as electrolytic tinning lines, side-trim and inspection lines, continuous annealing lines, recoil lines, and cold reduction mills. GE offers a somewhat similar system, costing from $75,000.

In an application on a tinning line the AI Data Accumulator, which sits right alongside the process line, is collecting a measure of the footage of prime quality sheet, the footage of reject material, the total number and location of defects, and the type of defects. In addition, such data as order number, crew number, and coil number are printed out as a permanent record of each roll produced.

The equipment to do this particular job includes three identical special purpose computers which operate in parallel on the same input information. A computer correlates a defect with its location on the fast-moving strip. The outputs of all three special purpose devices are compared; and if there is a difference, the majority rules, though there is a printout indicating that disagreement occurred on the location of that defect. Feeding the computer units are x-ray gage sensing elements which automatically spot defects and a visual inspection station from which an operator can spot defects and report them to the system as the sheet moves through the line at high speed.

Employee's reaction to all of the systems has been enthusiastic, particularly when their pay is based on incentives tied to ouput. In one Connecticut plant that installed the Productograph system on half of its machines as a test, the system prompted a union grievance within three months of installation—*by those employees who did not have the monitoring system on their machines.* Take home pay of those who had the system had increased so much from incentive payments resulting from increased production that the have-nots complained.

Bringing Hot Strip Mills Under Automatic Control

To achieve lower cost, better products, industry is placing larger and larger portions of its productive capacity under the supervision of integrated control and information processing systems, incorporating considerable computing ability because they can't be handled any other way. This first article tells how National Steel will employ a digital computer to bring a hot strip mill under complete automatic control for the first time. In the second article a digital computer controlling a thermal cracking furnace achieved a 10 percent increase in yield. The last article of the section describes process logic in applying a computer to automatically start electric generating stations.

DONALD BRISTOL, Daystrom Systems Div.
STEVEN KRAFT, National Steel Corp.

The first computer to control a hot strip mill brings automatic operation to a part of the steel plant that has previously defied the application of automatic controls. In the hot strip mill, which converts a heated slab of steel into a coil of sheet metal, the rolls of the mill must maintain only enough tension on the sheet to keep the metal moving so that gage is controlled only by roll setting; and the mill must turn out a variety of products—of different compositions, thicknesses, and widths—demanding that the program for roll screwdown and edge guide position change readily.

At the Great Lakes Div. of National Steel Corp. early next year, however, a Daystrom solid state information system will start controlling a 12-stand (plus two scale breakers) hot strip mill, capable of turning out 80-in. wide strip. In addition to setting the screwdown of the rolls, the roll speed, and the position of the edge guides, the general purpose digital computer system will punch out a paper tape record of each coil of steel produced; it will monitor key plant variables such as furnace temperatures, slab temperatures, and pressures, and alarm if vital functions like lubricating oil or steam spray are shut off during rolling; it will log a record for the accounting department and store the information to prepare a metal identification tag that accompanies each coil; it will program the changing of the rolls in the mill as they wear; and it will alter the program of screwdown and edge guide positions to turn out a variety of sheet products *without stopping* the mill.

By adding computer control, Great Lakes will be able to increase the mill's throughput of steel up to 100 percent, producing sheet at a rate of 3,000 ft per min—making it the fastest running hot strip mill in the country. And the computer system will hold the finished product to specifications more tightly than a human operator could. The Daystrom system is designed to run the mill 24 hours a day, seven days a week.

The first hot strip mill to be computer-controlled is being built for Great Lakes by the United Engineering and Foundry Co. It can be divided into two major parts (Figure 1): a roughing portion of five stands in which the slab is rolled to the proper width and gage dimensions to feed the second portion, the finishing phase. In the latter, seven stands convert the rolled slab to a coil of sheet in a continuous operation. In addition, the mill has a scale breaker located before the roughing stands and a scale breaker before the finishing stands. In between the roughing and finishing stands is a crop shear which cuts off the front end of the slab before it goes into the scale breaker which starts the finishing operation. The crop shear is the only part of the mill not controlled by the computer.

Processing the steel

The hot strip mill rolling process proceeds this way. The steel slab leaves a reheat furnace where it has been heated to rolling temperature and enters the mill. Scale is cleaned off by the scale breaker before the slab (or bar) enters the first roughing stand. The rolls of the roughing stands are screwed down and vertical edger rolls are positioned and their speed controlled to squeeze the bar to the proper width and thickness to enter the finishing stands.

That means each stand has an edge guide and a vertical edger as well as a screwdown roll to control. The edge guides are preprogrammed to position the bar into the rotating vertical edgers.

Leaving the roughing stand, the bar is held on a holding table until the finishing mill is ready to receive it, and enters a crop shear where the front end is cut off. The holding table gives the production process somewhat of a cushion in case the roughing end of the operation gets ahead of the finishing portion. In the finishing stands the metal is rolled to the specified gage. The seven stands squeeze the bar into a sheet about $\frac{3}{8}$ mile long. Since the seven finishing rolls operate in tandem, each succeeding roll rotates at a faster speed than the previous one. The sheet is directed to a runout table where it is cooled by water sprays. Then the sheet moves to a coiling roll which winds it up for shipment.

The computer continually monitors the thickness and width of the finished product, monitors such variables as the loads on each motor driving the rolls (finishing stands 2 through 6 have 8,000-hp motors), then updates the roll settings and speeds to improve the product. During rolling, steam sprays on the metal to keep the stock clean while the rolls are sprayed with water to keep them cool.

What the computer system does can be divided into three parts: scanning and monitoring, control, and display. The machine receives about 150 analog inputs and looks at 700 contact closures, sends out 200 digital control signals and 25 analog ones.

Monitoring key variables

Monitoring starts with variables in the reheat furnace and extends to the final coil. For example the computer scans furnace temperatures (40—10 in each of four soaking furnaces), fuel-air ratios in the furnaces (four), furnace water pressures so that the furnaces will not overheat and melt the slabs (four) and furnace stack pressures (four). On the mill itself the computer monitors roll balance pressures (seven—one on each scale breaker and each roughing mill), screwdown positions (14—two scale breakers, five roughing rolls, and seven finishing rolls), vertical edger positions (five—one on each roughing stand), side guide positions (15—one on each scale breaker and roughing stand, one between each finishing stand), speeds (12—five vertical edgers on the roughing stands and seven finishing stand rolls), looper positions (six—one between each finishing stand—to take up the slack in the sheet), slab temperatures (23—three prior to scale breaker and 20 not yet located), coil temperatures (two—one at exit of finishing stand and one in front of the coiler), and coil weight.

Certain mill operating variables are scanned too: hydraulic header pressures (two—water pressure to 1,500 psi), steam pressures (two), cooling water pressures, oil temperatures (48—to check the lubricating oil in bearings), and oil pressures (44). Finally, product dimensions are watched: width gages (two—one roughing and one finishing), and thickness gages (two—roughing and finishing).

The system alarms if the furnace zone temperature drops below a preset level (the computer could control this temperature too, but Great Lakes has no plans to perform such control), if steam or lubricating oil pressure drops to unsafe levels, if steam (for cleaning the steel) or water (for cooling the rolls) stops, or if the metal gets out of gage. Other alarms occur when stack pressure in the furnaces gets too low, when furnace water pressure drops too low, and when side guides move out of adjustment.

Controlling the mill

The control problem can be looked at in two big

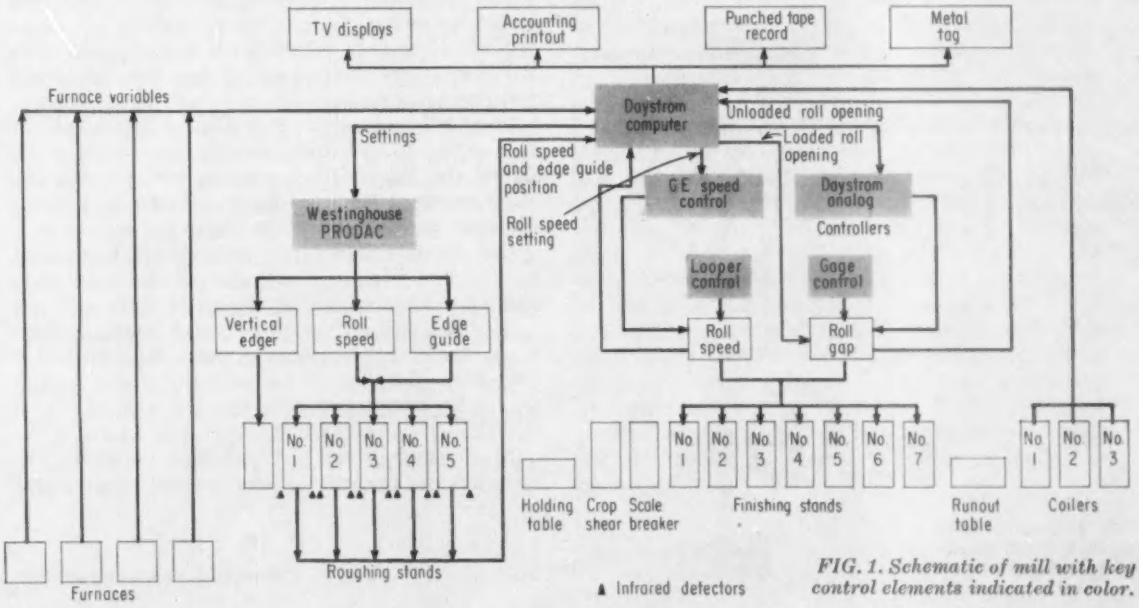

FIG. 1. Schematic of mill with key control elements indicated in color.

stages: roughing and finishing. The computer will direct both analog and digital servoloops to adjust each roll of the mill. The roughing portion will be equipped with Westinghouse PRODAC controls, which are digital, to control roll speed, vertical edger speed, and edge guide position; the finishing rolls will have General Electric static (solid state) speed controls (primarily for manual control) and Daystrom analog controllers to regulate screwdown, roll speed (operating through the GE control for speed), and edge guide position under automatic control. Daystrom valve controls will regulate the runout table sprays to maintain proper coiling temperature.

In the roughing stands, vertical edgers are chiefly responsible for maintaining the proper width. Each vertical edging roll is equipped with a tachometer which measures the roll's speed; the information is transmitted back to the computer. A synchro measures the position of the edge guide, prior to each stand, and transmits its intelligence back to the computer. The computer sets a proposed speed into the edger drive motors, then compares the programmed speed with that actually on the rolls.

Feedback in the finishing phases comes from tachometers on each roll (to measure the speed), synchros which measure the gap dimension (roll setting) of each roll, and x-ray thickness gages.

At each roughing stand an infrared device detects the position of each slab—as it approaches the roll, when it is between the roll, and as it leaves the roll. When a slab is detected approaching a roll, the infrared device turns on water and steam sprays; as the bar leaves the roll, the infrared device shuts off the sprays. But these detectors have an even more important information job. They keep the computer informed as to the progress of slabs through the mill so that the proper roll settings are applied to the right slabs.

There is a reason for this scrutiny. If for some reason a slab is delayed in the roughing end of the mill so that it cools, the slab is ejected from the mill and sold as plate. The slab following it may not have the same composition or be intended for the same gage sheet. The computer's program for each slab is prepared in advance, with a rolling schedule dependent on the composition of the slab and desired gage. And these programs are lined up in the computer, one after another. With the infrared detectors the computer is able to apply the right program to the right slab. If a slab is ejected from the mill, the computer learns this and passes that bar's rolling program.

In the finishing part of the mill there are some additional requirements which complicate the control job. For example, stand number four, called the anchor stand, always runs at a constant speed; stands in front of it and behind it are speeded up or slowed down. Stand number seven, the last one, always reduces the sheet only 10 percent in thickness. This reduction is kept minimum so that the final finishing roll will put a smooth finish on the sheet and turn out good-looking product.

Although the computer inserts speeds and roll settings into the controls of each finishing stand, actual control is modified by two subloops. The looper control corrects speed; an automatic gage control modifies roll setting.

Because the speeds of all seven rolls are related, changing one would mean changing all of them—and the problem is additionally complicated because the speed of number four roll cannot be changed and number seven's speed is closely restricted. To do this computation even on a general purpose computer would be terribly complicated. Instead, the hot strip mill will have looper controls between each finishing stand to help alter the roll speed.

Object of the looper control is to keep the strip at a constant height between stands and at minimum tension as it passes through the mill. It is a spring loaded roller that can rise or fall as needed to keep the strip at constant height (Figure 2). As the looper's roll moves, it sends correcting signals to the motor of the roll, adjusting the speed until the looper has moved back to preset position.

Finishing stands 2 through 6 are equipped with automatic gage control which has two additional functions.

How this automatic gage control works can be seen in Figure 3. The computer inserts (as an analog signal) the unloaded roll opening setting before the sheet arrives at the roll. Each roll, of course, has a different setting. Then the computer inserts, as a digital signal, a loaded roll opening which is added to a reading from an x-ray gage, a position detector, and a roll detector, to reset the speed of the roll.

The unloaded roll opening signal is analog because it operates directly on the screwdown drive, an analog controller. The loaded roll setting is digital so that it will be compatible with the GE control which is digital.

At the end of the finishing line, an x-ray gage measures the thickness of the finished product and

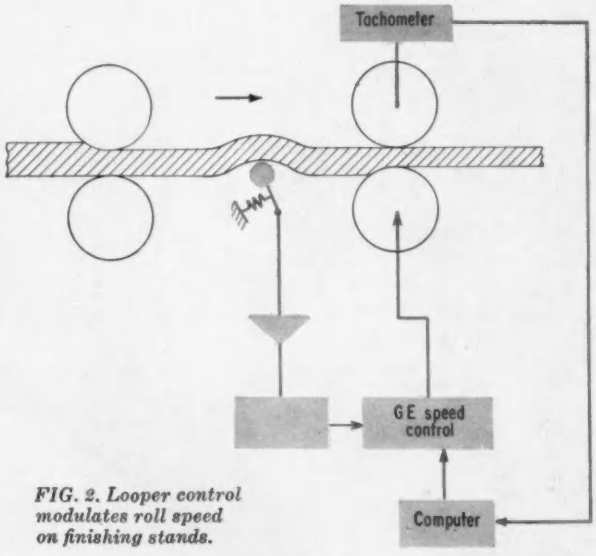

FIG. 2. Looper control modulates roll speed on finishing stands.

sends this information back to the computer where it is stored and the computer evaluates how well the entire control has performed. If the sheet is on gage, the computer will then check to see if it was rolled under optimum conditions. The machine will attempt to optimize power; that is, since most of the stands have 8,000-hp motors, it would be inefficient to have one stand operating at 8,000 hp and another at only 4,000 hp.

In addition, the computer will check settings it has put into the control and compare those with the settings that were actually used. For example, as previously mentioned, the looper control will modify the speed of the roll. If the looper control was very active, the computer will change its setting so that the looper will not be used as much on the next slab processed under these same conditions. Then it will look at screwdown position, as set by the automatic gage control. If the gage control is screwing the rolls down well beyond the setting the computer introduced, the machine will change its unloaded roll setting for the next slab.

If the sheet is out of gage, the computer will perform computations to determine what should be done to remedy the situation.

The Daystrom information system will also determine when the operating crew should change the rolls of the mill because of wear. Rolls are changed after they have passed over a certain tonnage of metal. During operation of the hot strip mill turning out strip at speeds of 3,000 ft. per min, one roll may have to be changed every hour; changing requires about 4 min. As the mill operates, the computer will add up the footage that passes over each roll and will advise when it is necessary for each roll to be changed.

Displaying performance

For the display portion of the system, the computer will print out key variables on an electric typewriter. These will include all mill variables for every slab, including roll settings and speeds, side guide settings, order number, and finishing width and gage. A television camera will flash this displayed information to six locations along the mill. The operating team will be able to tell from the TV monitor what their settings are. In addition to viewing by five operators, the information will be displayed at the delivery side of the reheat furnace.

A second printout will be prepared for the accounting department. The chart (at right) indicates what variables the accounting department will receive for this historical log. Another output will be a punched paper tape, one for each coil produced. The dimensions of the finished product are divided into 10 separate categories, five below specification and five above. The punched paper tape will contain this type of information: grade no. 6—2,000 feet; grade no. 7—1,000 ft.; grade no. 8—400 ft., etc.

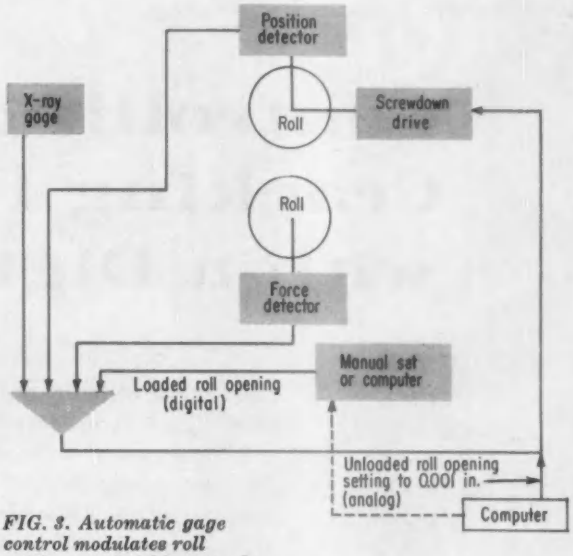

FIG. 3. Automatic gage control modulates roll settings on finishing stands.

ACCOUNTING DEPARTMENT PRINT OUT

Order number	Finished weight
Heat number	Coiling temperature
Slab number	Date
Slab number in order	Tolerance
Slab length	Delivery thickness out of last roughing stand
Slab width	Time slab started and completed
Slab thickness	Percent yield
Slab weight	Percent off gage
Metal specifications	Percent off width
Finished gage	Shift number
Finished width	
Finished temperature	

There is one other output of interest. The computer will store enough information to prepare a metal identification tag which is attached to the finished coil. The tag contains such information as the furnace which supplied the steel, stand settings, order number, the heat number, metal specification, finished gage, finished width, coil weight, and coil length.

From an arithmetic standpoint, most of the computations the computer will perform are simple. For example, it will compute incentives for the operators, a straightforward calculation, and it will calculate percent yield based on the weight of the incoming slab and the weight of the finished coil. But one computation will be complex—and it represents a major innovation in the steel industry. Great Lakes, Daystrom, and mill designer United Engineering will try to convert the empirical mill schedule curves to a generalized equation which the computer will be able to solve. If this is accomplished, the computer will be able to compute what roll settings to use at what speeds to produce a desired gage of any specific metal.

Controlling a Thermal Cracking Furnace with a Digital Computer

THE GIST: Convinced that the potential value of digital-computer direction of a production process outweighs initial technical and economic risks, Phillips joined with Autonetics in an experimental program to explore computing-control. The program, carried out on a thermal cracking furnace, showed that:

- *A 10-percent increase in ethylene production was achieved by first using the computer for process analysis and testing to provide information on the best way to operate the furnace. Employing these new facts, just a few months' production operation at this increased rate—*without *a permanent computer installation—paid for the entire experimental effort.*
- *An additional 6-percent increase in ethylene production from one furnace—but* with *a permanent on-line computer to maintain this increase—was obtained by using the computer to continually operate the process at maximum safe conditions.*

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The thermal cracking process in Phillips' ethylene plant at Sweeney, Texas, chosen for the experimental digital computer control program, employs several parallel furnaces to crack light hydrocarbon feedstocks, thereby yielding ethylene and other products. The ethylene is subsequently used to produce Marlex, Phillips' high density linear polyethylene. The product's value is so large that small percentage increases in throughput or yield may easily justify a computer system. Inherent operational problems indicate potential substantial improvements: carbon buildup inside the furnace tubes, determining conversion and product distribution in furnace effluent, and determining tube skin temperatures.

The Process and Its Objectives

The process consists of several Selas cracking furnaces. Each furnace can charge propane, normal butane, or ethane. Figure 1 shows a furnace and its control system. The hydrocarbon feed is diluted with steam, the only other material present, and fed into the convection section's two parallel coils. These coils converge to a single shock and radiant coil. For propane cracking the inlet conditions are 260 deg F and 60 psig. Outlet: 1,500 deg F, 10 psig.

Products are formed by endothermic thermal cracking. Furnace effluent composition consists of at least 16 components ranging from hydrogen to tar and carbon, with the effluent typically containing 20 to 40 mol percent ethylene.

As shown in Figure 1, three manipulated variables are adjusted by the computer during closed-loop operation. Otherwise, setpoint adjustments are made manually. These manipulated variables are the hydrocarbon and steam feed flows and the Tube 3 gas temperature. The temperature recorder controller TRC cascades into a fuel gas header pressure recorder controller PRC, the output of the TRC resetting the PRC's setpoint. Firing conditions are manually adjusted by two stack dampers and by a Merco valve on each of eight headers (four on each side) with each header feeding 12 burners.

Key operational factors are conversion, the percent feed destroyed, and ethylene yield, the pounds of ethylene per 100 pounds of feed destroyed. Conversion, a function of the area under the residence-time vs gas-temperature curve (Figure 2), depends on throughput, heat input, and furnace pressure. If throughput decreases, residence time, area under the curve, and conversion will increase.

Ethylene yield is a function of conversion, outlet pressure, throughput, steam-to-hydrocarbon ratio,

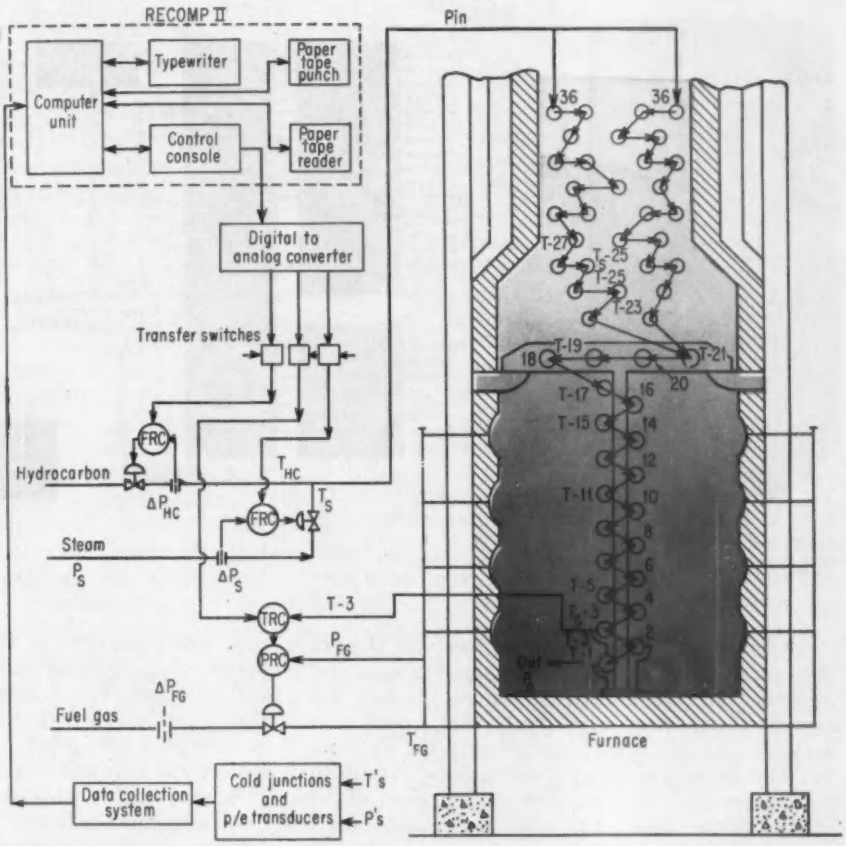

FIG. 1. Phillips ethylene thermal cracking furnace operates under closed-loop control of an Autonetical RECOMP II digital computer.

and gas temperature profile. Over the range of interest, yield is a direct linear function of *conversion*. As *outlet pressure* increases, yield decreases. As *throughput* increases, residence time decreases, tending to increase yield. At the same time average cracking pressure increases, tending to decrease yield. Over a range of throughputs these effects cancel and no change in yield is observed. However, a point is reached where the nonlinear throughput-pressure relationship overcomes the residence time effect, and yield decreases as throughput increases. An increase in *steam-to-hydrocarbon* ratio causes a decrease in hydrocarbon partial pressure and results in increased yield. A *gas-temperature profile* with short residence time at high temperature will result in increased yield.

Tube skin temperature limit adds a constraint to the foregoing complex relationships. For example, increases in throughput and temperature, at constant conversion, demand increased heat fluxes and skin temperatures which may be metallurgically unsafe.

The basic control objective was to manipulate these interacting relationships for maximum throughput without exceeding skin temperature limits.

Control System Equipment

At 35-ft air conditioned van, parked near the ethylene plant control room, housed the data collection system, the Autonetics RECOMP II digital computer, and the digital to analog converter. The interconnection of these units with the process furnace is shown in Figure 1, above.

The data collection and sequencing system developed by Phillips, Figure 3, sequentially examines 23 inputs at one point per sec. Transducers convert the 3 to 15-psig pressures and differential pressures

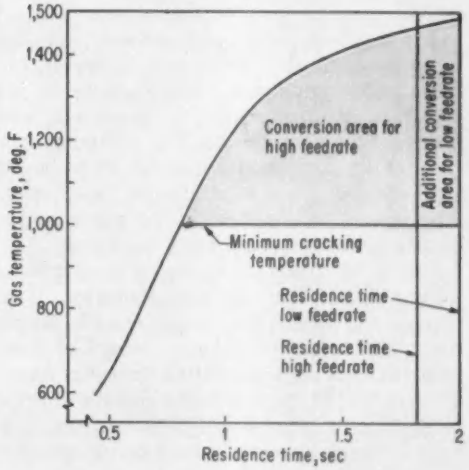

FIG. 2. Conversion of the hydrocarbon feed in the thermal cracking furnace increases as the area under the residence-time vs gas-temperature curve increases.

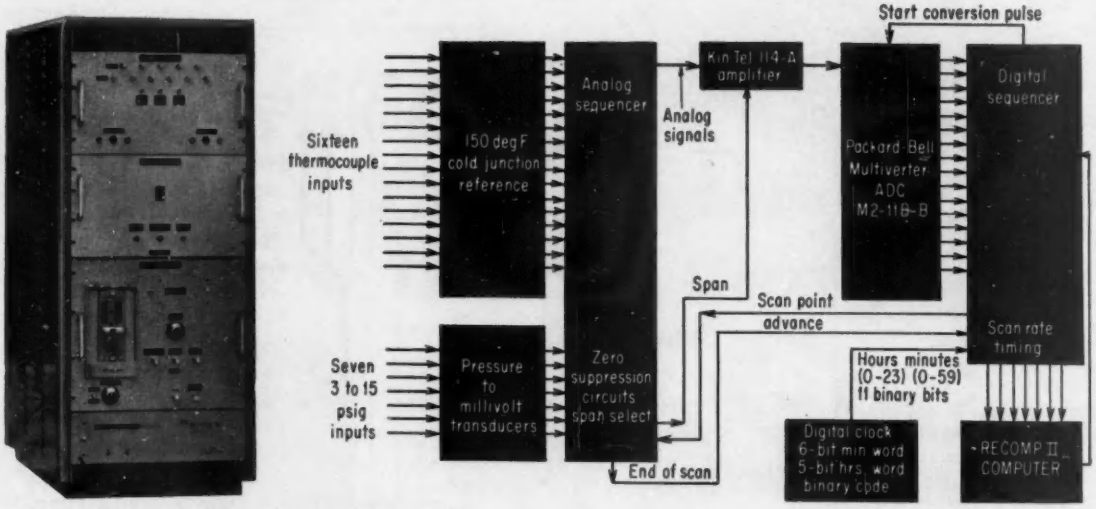

FIG. 3. Data collection and sequencing system developed and built by Phillips scans 23 analog inputs and digitally codes them for the computer.

to millivolt signals. The analog sequencer chooses the proper zero suppression and amplifier span and feeds the selected millivolt signal to the Kin Tel amplifier. All amplifier outputs thus range from 0 to minus 9.775 volts. Subsequently the Packard-Bell Multiverter converts the analog voltage signals to a digital output of 0 to 1,000 in the form of 10 parallel binary bits. The digital clock, however, delivers 11 parallel binary bits for hours and minutes.

The digital sequencer accepts the Multiverter and digital clock parallel outputs, generates the necessary zeroes to produce a fixed length computer word of 15 bits, and presents the data to the RECOMP II —which accepts five parallel bits—as three serial groups of five parallel bits. The "start scan" signal comes from the computer, but once started the data collection system runs at its own rate. The computer accepts one word and is ready for the next before it becomes available from the sequencer.

RECOMP II, made by Autonetics, a division of North American Aviation, Inc., is a fully transistorized, general purpose digital computer. It features small-computer compactness and operating economy with the power and versatility of a medium scale computer. Outstanding are its extensive command structure, two commands per word, and floating point hardware. The computer comprises computing, control, and memory units housed in a single cabinet, photoelectric paper tape reader, paper tape punch, on-line electric typewriter, and control console with numerical entry keyboard.

Digital to analog conversion is accomplished by a pulse width to shaft position converter. The Nixie tube on the RECOMP control console, by programming, displays any digit for any length of time. The program bases digit selection and display time on the setpoint that is to be adjusted and the direction and magnitude of adjustment. For example, displaying digit 2 means increase Tube 3 gas temperature to a new value equivalent to the display time. The particular digit displayed sends a unique combination of 0 and minus 40-volt signals through a diode matrix that selects which two of four selection circuits will be energized to further determine which of three motors will turn and its direction of rotation.

At rest, each motor shaft serves as a memory. Coupled to the shafts are shaft position to pneumatic setpoint transmitters which feed through transfer switches to pneumatic set controllers. Setpoint transmitter output does not change if power fails.

Computer Programs

Once the constant data is loaded into the computer, the control system functions are carried out by load data, furnace, control, and reset programs. The entire program contains about 5,000 commands, many used repeatedly, and 750 stored constants.

The *load data program* provides correct numbers. Digital input for each variable is collected, stored, and used to solve engineering unit equation:

$$EU = A + BD + CD^2$$

where A is zero suppression, B is span, C is linearization, and D is the digital value obtained from the Multiverter. The selection of good data is required for accurate computation. Therefore, each variable is checked against fixed high and low limits and each set of data after the first is checked against the previous set for rate-of-change limit. The computer continues asking the data collection system for sets of data until three successive good sets are obtained. The computer then averages the data for each point and prints out the load data. Variables which require further computation are then processed.

With good load data available, the computer proceeds to the *furnace program* which carries out the calculation based on a mathematical model previously developed for designing furnaces by an off-line computer (Reference). To make this calcula-

tion the furnace is divided into 16 increments. Increment size varies from one to eight tubes in length. Hydrocarbon feed cracking is calculated progressively, starting with the eight-tube increment at the furnace inlet where no cracking takes place.

For example, at the furnace inlet the pressure, temperature, composition, and total feed rate are known. The computer calculates, for the first increment, effluent gas pressure and composition, conversion, average heat flux, and average skin temperature of the last tube in the increment. Increment outlet temperature is measured and known. Using these outlet conditions for the first increment as the inlet conditions for the second increment, the furnace program proceeds down through the furnace, increment by increment. Outlet conditions for the final increment are the furnace outlet conditions.

Based on the data now available, showing where the furnace is being operated, the *control program* calculates new setpoint adjustments necessary to operate the furnace at a production optimum and still be within the boundaries for protecting equipment and personnel. Process controller setpoints are adjusted manually by the process operator from printed operating guides or by the computer itself via the automatic setpoint adjustment. *Reset program* prepares the computer for the next run.

Plant Programs

After installing the computer system, the furnace was operated at high and low conversion levels to determine the model's ability to follow actual furnace changes. The stoichiometric equation constants were adjusted until conversion accuracy was plus or minus 2 percent and yield accuracy plus or minus 5 percent of their measured values. This accuracy can be improved by further effort. The computed conversion and effluent composition were verified by comparing them with independent sources of plant data: a laboratory mass spectrometer, on-line chromatographs, and plant material balances. The skin temperature calculations were verified by comparing with skin thermocouple measurements.

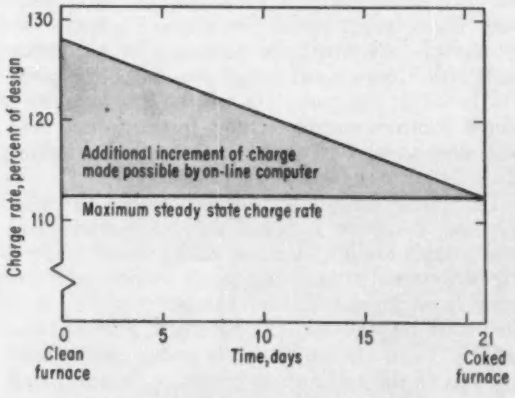

FIG. 4. Using the computer for on-line control permits the furnace to be run at highest safe tube skin temperatures, thereby adding valuable increment of throughput capacity.

Aided by the computer, the systems team determined that a shift in the furnace firing pattern allowed the charge rate to be raised 12.5 percent above the normal (design) rate at constant conversion. Ethylene yield decreased at the higher throughput so that ethylene production increased 10 percent. The change in firing pattern increased the heat flux and corresponding gas and tube skin temperatures in the upper part of the radiant section.

To justify an on-line computer control system, the process must be subject to frequently occurring disturbances. A study of cracking furnace operations showed only one major disturbance: the gradual formation of carbon reduces heat transfer through the tube walls. Carbon buildup ordinarily causes the furnace to be shut down about every three weeks. During shutdown the furnace is burned out and left clean of carbon for the start of the next operating period. For the same differential temperature across tube walls, more heat can be transferred when the furnace is clean than when it has a carbon deposit: the furnace has a higher capacity when clean than when coked.

Figure 4 illustrates this idea. The triangular area represents an added increment in charge rate which is not available without an on-line computer because it is too risky to run at the skin limit without adequate knowledge of skin temperature.

Several tests verified this premise. With a clean furnace the charge rate was raised to 128 percent of design. As the furnace coked, it was necessary to reduce the charge rate gradually to 112 percent of design by the end of the operating period. The average charge rate over the operating period was 120 percent of design. Thus an 8-percent increase in charge rate was realized with a resulting 6-percent increase in ethylene production. The carbon laydown disturbance cannot be eliminated, but maximum, safe use of process equipment prevails at all times during the disturbance period with on-line computer control.

The data acquisition system worked faithfully during the entire seven-month program because of its simple design and low use factor. Experience with the RECOMP II indicates that it is reliable and requires little maintenance. Before obtaining satisfactory performance, however, a run of computer system trouble was experienced. The basic trouble was typewriter timing contacts. In fact, most hardware problems were traced to the typewriter. Fortunately, few of these annoying troubles caused complete system failure.

After the tests were completed, the van and computer system were removed from the plant. This equipment will be used to evaluate computer control for other petroleum and chemical processes.

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TUBE BY TUBE DESIGN OF LIGHT HYDROCARBON CRACKING FURNACES USING A DIGITAL COMPUTER, A. J. Andrews and L. W. Pollack, "Industrial and Engineering Chemistry," February 1959.

Starting an Electric Generating Station -Automatically

THE GIST: The idea of using control computers in the electric generating industry is no longer novel. Economic justification appears favorable, particularly if a dollar value is assigned to increased safety, and firm commitments have been made to place digital control computers at the helm in accomplishing operational, managerial, and custodial functions for new generating units.

The success of these installations depends, however, on a clear delineation of the tasks to be accomplished in running a plant, which tasks the computer control system can perform, and then a study into exactly how the computer can effect the necessary actions. As an example of a detailed computer program for automatic operation, the author describes just one of the computer's many jobs: cold startup of a coal-fired generating unit.

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The control system for the automatic electric generating station, using a master digital computer directing subloop analog controls, is shown in Figure 1. A request to start or stop the plant or to change load or reactive will enter through the master computer controller. The computer extracts from its memory the proper actions to be taken—after considering the plant dynamics—and generates the necessary start-stop commands for plant auxiliary equipment and the temporary or normal setpoint or other signals to the major analog subloops. The subloops continuously control important plant variables like governor position; combustion; feedwater flow; and steam, hydrogen, and oil temperatures.

The scanned results are evaluated by the computer to see that the instructions are properly carried out. The computer will print operating, performance, and historical information and records of external requests and uncontrolled variables changes and of its own actions to meet such requests and changes. In addition, the computer will advise the human supervisor of any abnormal conditions with which it cannot cope. The automatic plant also includes a separate safety system to detect unsafe conditions and initiate automatic shutdown when necessary.

When the computer detects an unusual deviation in a subloop controlled variable which cannot first be corrected within that loop, it will make compensating adjustments in other controllable loops. If that action is not sufficient, the computer will remove from service part or all of the offending subloop control and directly set the final actuator to a safe, but perhaps not the most efficient, position. If the computer detects a potentially unsafe operating condition—before reaching the limits of the separate safety system and if computer internal checking shows proper computer action—the computer can initiate starting of alternates and orderly shutdown of minimum running equipment.

Combustion control will be a continuous analog system, having the usual inputs and the cascading, fuel cutback, and minimum-air features normally provided on conventional combustion control. However, the setpoint signals for pressure, oxygen, and individual feeders will be generated by the master computer from stored programs and calculations. Furthermore, the computer will be programmed to adjust controller-mode settings (proportional, reset, and rate) as needed to produce optimum stability at the setpoints called for by the computer.

The master computer will also control the effectiveness of the tie between the combustion, feedwater, steam temperature, and draft controls by sending feedforward anticipatory signals to these and other controls on receipt of load change requests. Since the computer will also calculate heat rate and coal quality, it can change setpoints and alter the interrelations of the subloops to obtain optimum operat-

ing efficiency for uncontrolled conditions like load demand, ambient air temperature, circulating-water temperatures, slag conditions, and mill wear.

Automatic plant startup

The foregoing description reviewed briefly the over-all task of the master digital computer controller in operating the automatic generating station. However, successful realization of an automatic generating plant requires considerable time and effort in determining those detailed procedures by which the computer will make operating decisions and execute the necessary actions in a manner that is orderly, safe, and efficient.

The operating method is described by sequence and logic flow charts which are later rewritten by computer programmers into computer language. The box details six primary functions performed by the computer. Attention to detail is mandatory. Determining the program is important and challenging, yet tedious and time consuming.

To see how complex and detailed the computer program actually becomes, consider just one major function, that of cold startup of the electric generating unit. Assume the plant has a coal-fired steam generator with oil for warmup fires, a steam-sealed, hydrogen and liquid-cooled turbine generator, and motor-driven major auxiliaries. Only an abbreviated version can be given here: first to be described is a simplified starting program, then a portion of the main starting sequence, and finally most of the sequence related to starting a coal mill.

Figure 2 illustrates the simplified procedure for starting plant equipment. Preliminary processes, inspection to determine that personnel are not inside the equipment, and release of equipment to computer control are performed by a human being. Then the computer initiates filling of necessary tanks and pipes. The turbine generator is placed on the turning gear to straighten the shaft. The furnace must be purged and warmup fires lighted.

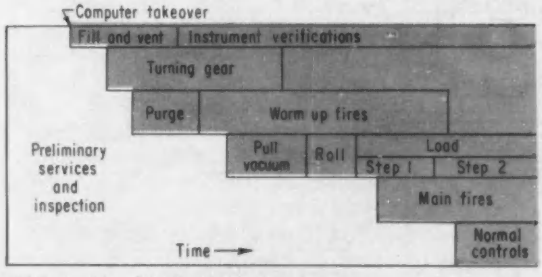


FIG. 2. Simplified starting program for the automatic central station.

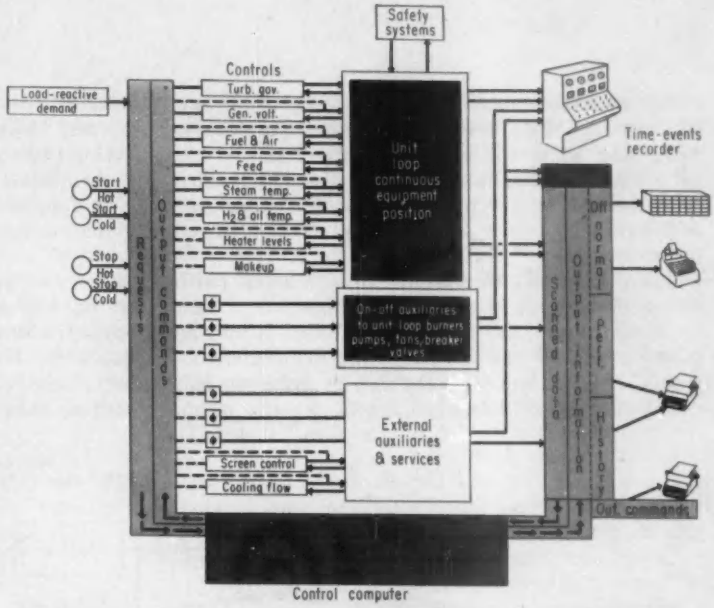


FIG. 1. The automatic generating station using a digital computer as the master controller.

The turbine is then sealed, condenser vacuum established, and the machine rolled with steam. After reaching rated speed, the generator is synchronized to the power system and initial load picked up. The main coal fires are started, additional load picked up, and normal combustion and draft control switched into service. The computer checks the instruments and controls all during startup.

Main starting program

The second half of the general starting sequence is shown in Figure 3. Prior to this, briefly, the

SIX MAJOR COMPUTER ACTIONS FOR AUTOMATIC PLANT STARTUP

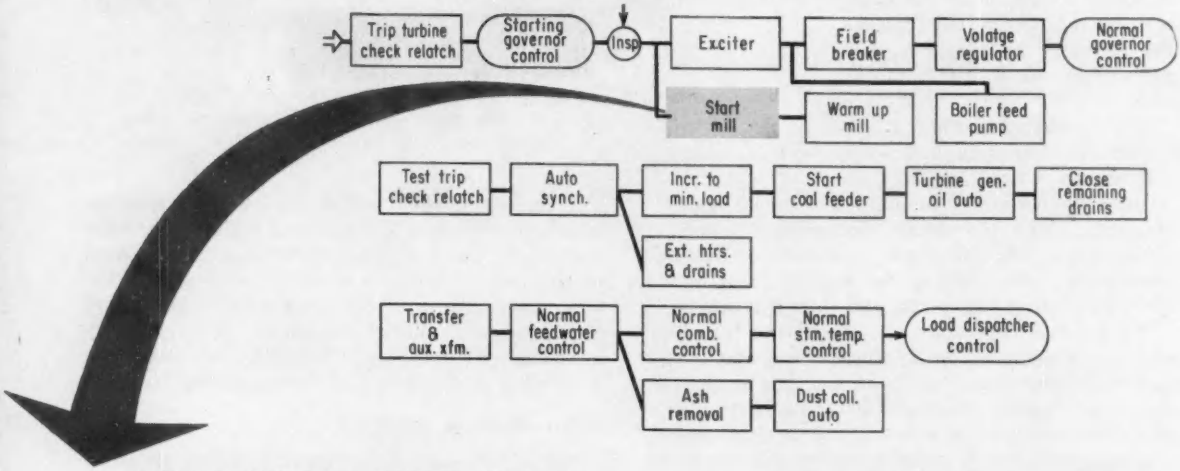
The plant startup sequence proceeds as directed by the computer's stored program. However, for each succeeding step to occur, certain conditions as to the magnitude of plant variables and the state of plant equipment must be met. Thus, at appropriate times the computer will also call for measurement to determine values of significant continuous variables and of opened or closed position of signal contacts as from a bearing-oil pressure switch. Sometimes starting sequence continuation depends on a calculation. Furthermore, the computer subjects measured and calculated values to a reasonableness check to prevent a possibly unsafe action based on instrument or computer errors. The computer also makes logical decisions as, for instance, a coal feeder will not be started unless water is flowing to the mill-oil cooler AND the oil temperature is between 50 and 90 deg F. Successful completion of operating action permits the sequence to proceed.

computer has commanded and has been assured that all necessary steps have been taken preparatory to firing the boiler for warmup; ignitors turned on; oil guns inserted, lighted, and proved; machine rolled with the starting governor; and lube oil temperature and hydrogen cooler and stator-oil coolers placed on control.

Then (Figure 3), the turbine trip is actuated (with steam flowing) to check its trip function. After resetting the trip, the machine is returned to starting governor control and the programmed increase continues. Exciter voltage is checked at above one-half speed and the field breaker closed. In the meantime the first coal pulverizing mill should be warmed up, and by this time the boiler pressure will be high enough to require starting a feed pump.

At normal speed the oil trip is tested and reset. Synchronizing the generator output to the power system is accomplished by a subloop and checked by the computer. When the generator breaker closes, the master computer increases the governor setting to minimum stable load. This load is held while the first coal feeder is started and coal ignition checked. The turning gear and auxiliary oil pump are placed on automatic, the heater drain pumps started, and extraction line drains closed.

FIG. 3. Part of general plant starting sequence.



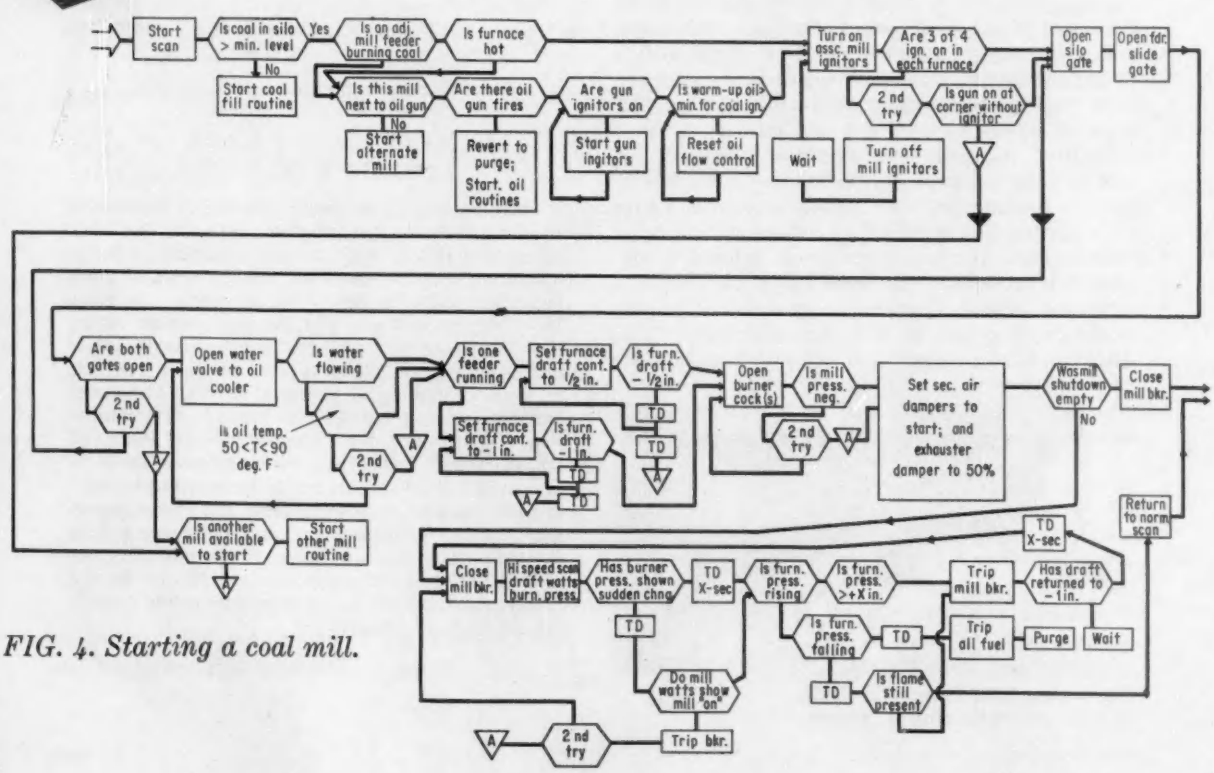

Start scan
Is coal in silo > min. level
Yes
No
Start coal fill routine
Is an adj. mill feeder burning coal
Is this mill next to oil gun
No
Start alternate mill
Is furnace hot
Are there oil gun fires
Revert to purge; Start. oil routines
Are gun ignitors on
Start gun ingitors
Is warm-up oil> min. for coal ign.
Reset oil flow control
Turn on assc. mill ignitors
Are 3 of 4 ign. on in each furnace
2 nd try
Is gun on at corner without ignitor
Wait
Turn off mill ignitors
A
Open silo gate
Open fdr. slide gate
Are both gates open
2 nd try
Open water valve to oil cooler
Is water flowing
Is oil temp. 50<T<90 deg. F
2 nd try
Is another mill available to start
Start other mill routine
Is one feeder running
Set furnace draft cont. to -1 in.
Is furn. draft -1 in.
Set furnace draft cont. to -½ in.
Is furn. draft -½ in.
TD
Open burner cock(s)
Is mill press. neg.
2 nd try
Set sec. air dampers to start; and exhauster damper to 50%
Was mill shutdown empty
No
Close mill bkr.
Return to norm scan
TD X-sec
Close mill bkr.
Hi speed scan draft watts burn. press.
Has burner press. shown sudden chng
TD X-sec
Is furn. press. rising
Is furn. press. >+X in.
Trip mill bkr.
Has draft returned to -1 in.
Is furn. press. falling
Trip all fuel
Purge
Wait
Is flame still present
Do mill watts show mill "on"
2 nd try
Trip bkr.

FIG. 4. Starting a coal mill.

The auxiliary electrical equipments are transferred to the auxiliary transformer. The initial pressure regulator is cut in service when its setpoint is reached. Then load pickup continues to the range where normal combustion, feedwater, and steam temperature controls can be placed on automatic, but—if at this stage of sequencing their setpoints have not been reached—the master computer will instead program the further rise in setpoints with all subloops on automatic. Dust collectors and ash removal systems are now placed on the line. When sufficient coal fire is attained, the warmup and stabilizing oil guns are shut off and removed, and soot blowing is placed on automatic.

As load is increased by dispatcher command, the master controller then warms up, starts, and feeds other mills. Additional fans, boiler circulating pumps, boiler feed and condensate pumps, and circulating water pumps are started as required.

Starting a coal mill

The major portion of the program for starting a mill, Figure 4, details some of the intricate functions accomplished by the master digital computer. This program illustrates one of several ways to start a Raymond coal mill, assuming that at some previous time the warmup oil guns and ignitors have been lighted and thus should be burning. All running equipment is continually verified by the computer.

The master will start scanning the associated watts, pressures, temperatures, and switch positions; will check for coal in the silo; and check to see that the mill to be started is one for which an oil gun (for coal ignition) has been provided (AND is NOT unavailable for use) OR that its burners are adjacent to those of a mill which is already burning coal. If neither condition exists, another mill will be selected to start. If the "gun" condition is met and the ignitors associated with the oil gun are on, and there is a main oil fire and there is sufficient warmup oil flow to ignite the coal, the program will proceed. If insufficient oil is flowing, the program will raise the setpoint of the oil flow control (and associated air) until sufficient oil is burning.

Ignitors associated with the coal nozzles will then be energized and checked. At least three of the four ignitors in each furnace must be on to proceed—without human intervention. The silo gate and feeder slide gate are opened. However, if both gates do not open, the gate-opening procedure will be tried again; and if this is not successful, the gates are closed, an alarm is sounded, and the program seeks another mill to start. When both gates open, then the mill oil-cooler water valve opens, and a check is made to see that the water is flowing and the oil temperature is between 50 and 90 deg F.

If coal is not already being fed to the furnace, the furnace draft control will be gradually set to minus 1 in. water gage pressure and a measurement made to verify whether this condition is obtained. If some other mill and feeder is running, the draft will be gradually set to minus ½ in. and checked. The burner cocks will then be opened and note made if mill pressure becomes slightly negative. Secondary air dampers are set to their starting position, the exhauster discharge set to 50 percent, and the computer memory interrogated to see if the mill was empty when last shut down. If the mill was empty when last stopped, the mill circuit breaker will be closed, and the associated variables scanned for corrective actions.

However, if the mill was stopped with coal in it, the program will "branch" into a subroutine program causing the mill to empty by "bumping". The coal feeder is still off. This subroutine will start the mill as well as the high speed scanning of furnace draft, burner pressure, and mill watts. As soon as burner pressure builds up, a time delay will be set, mill watts checked for above-normal running value, and the furnace pressure checked for ½ to 1 in. positive pressure. If furnace pressure has reached this high limit, the mill circuit breaker is tripped, the draft allowed to return to minus 1 in., and then the operation is repeated. This bumping operation will continue until the mill does not produce unusual positive pressure before mill watts have returned to the value associated with an empty mill (after the starting current surge), in which case the mill will be permitted to run.

However, in this subroutine if after energizing the mill the furnace pressure goes appreciably negative instead of positive, it would indicate that the coal just admitted has smothered the ignition fire. The computer would trip the mill and all other fuels and then initiate a purge cycle. When the mill is started and the furnace pressure does not go significantly positive or negative even after time delay greater than an empty mill would cause, the flame detectors will be checked. If they also show an adequate fire, the mill will be permitted to run.

The balance of the mill and feeder starting program, not shown, includes opening the blast gate, setting mill temperature control, setting feeder to starting speed, seeing if main program wants coal fed into the furnace, and then starting feeder.

The preceding partial program for coal mill startup represents only a fraction of the total program for automatic central station operation. No wonder many man-years are needed just to delineate the operating method for computer control of the entire generating unit in sufficient detail to permit translation into a computer program. Even then it would be foolhardy to believe that initial programs are optimum. A shakedown period is required to tune the program to actual equipment characteristics and operational requirements. Fortunately, the flexibility of the stored-program digital computer makes program changes easy—even after installation.

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CENTRAL STATION CONTROL—AUTOMATIC STARTING, W. A. Summers, 2nd annual ISA National Power Conference, Kansas City, Mo., May 11-13, 1959.

AUTOMATIC METALWORKING: a status report

Discrete piece production presents something of a reverse trend to the encompassing scope of automatic systems described in the preceding two sections Because in the major part of the metalworking industry production runs are small, individual machine tools under human guidance remain the basic manufacturing means. Recently the concept of numerical control has received wide attention as a means for automating individual machines. Tape controls are unquestionably coming into use; but at what rate and on what types of machines? The year 1960 is a propitious time for finding the answers to these questions directly. This month the once-every-five-years Exposition of the National Machine Tool Builders Association takes place in Chicago. Traditionally, this is the showplace of the latest in a metalworking techniques. To preview the Exposition CONTROL ENGINEERING *Associate Editor Cooney visited the plants of over 50 machine tool companies and was privileged to share some closely guarded secrets. Herewith is his status report on automatic metalworking.*

JOHN D. COONEY, Control Engineering

Handicapped by unrealistic tax rules on depreciation, demoralizing feast-or-famine sales curves, and conservative management, the machine tool industry has been historically slow to change. Its progress from lineshaft drives through machinery electrification to transfer-type automation moved sluggishly over a span of many years. Now in this most unlikely of climates comes an almost overnight change—to numerical control.

An observer on the metalworking scene is likely to take this news casually, since 1960 is an Exposition year and a bit of a splurge on punched tape might well be expected. But in the quiet away from Chicago he can never suspect that a revolution has actually taken place. Only the clacking tape readers, the spinning tool changers, and the X-Y-Z gyrations of the cutting tools on literally hundreds of machines on the Amphitheatre floor can lead to full understanding of what the control engineer has wrought in metalworking. There visitors will find more new machines and more new control systems than were ever before revealed during the long history of the National Machine Tool Builders Exposition.

In retrospect the reasons for the dramatic and sudden upgrading of machine tool technology are logical and clear. First, many good tape systems are now available; and control builders, having begun to taste sweet profits after years of shelling out research and development money, are pushing hard to sell them. Then too, machine tool builders have become willing prospects, seeking some innovation that could possibly spark sales and raise the industry to better levels of operation. Some of their group, who early saw the potentials of numerical control, have already enjoyed a tape-triggered business upturn. Lastly the economic benefits of numerically controlled metalworking are becoming well documented so that interest is turning to enthusiasm at the user level.

For numerical control the unveilings of September 1960 are the culmination of a long, hard climb from the modest beginning made at the 1955 exhibition, which featured only a few tape systems that were a serviceman's nightmare to keep running. Curiously enough, few of the other control novelties introduced

at the time have had nearly as much success. Electrolytic machining has become widely used as has in-process gaging which will be routinely displayed as standard equipment on grinders. But the wired-in wiring diagram, which promised to relieve maintenance headaches, has met with little success and will not be seen this year. Nor will statistical quality control techniques applied to in-process feedback gaging. Miniature relays have fared a little better, being used on several panels in show machines. The most notable casualty among promising machine tool control components is 1955's star, magnetic amplifier static switching. Transistor switches will be seen in profusion (notably in tape control circuitry) but the magamp will be hard to find.

Tape trends

In point of numbers, machines of the drilling and boring classification rank Number 1 in the lists of numerically controlled machines. Despite the large ratio of control cost to machine cost, drilling machines have found extremely good user acceptance. Machine builders are now offering a wide range of capacities both in spindle horsepower and in swing. Several machines are equipped for control of spindle depth as well as the *X* and *Y* table movements. Several manufacturers have added turret drills to their lines, one having a tape-programmed turret with 32 tools.

In the tool-changing "manufacturing machine" category, several new designs have joined the now-famous Milwaukee-Matic. A huge version of the latter, with workpiece size capacity doubled in all axes, is now available. The area of greatest divergence in the design of these machines is in the approach to tool changing. Some favor completely automatic changing, while at least one skirts the difficulties sometimes associated with this feat by programming a "tool presenter" and requiring the operator to do the actual changing. Tool capacities, too, vary widely. Fosdick has designed a 100-position tool magazine, while Natco is sponsoring a machine having two spindles and two tool changers.

The milling machine story seems to center around new control systems. Minneapolis-Honeywell marks its entry into the field with a three-axis point-to-point control applied to a Famco mill. The most unique feature of this system is the use of binary-coded cams and an optical scale for coarse and fine feedback. As far as path control is concerned, Bendix and GE have launched two completely new systems designed to overcome the difficult programming and high cost which have stiffled the acceptance of tape controlled contouring. Both controls are radically different from the original versions marketed by these companies and are capable of both linear and circular interpolation without the use of separate directors.

The biggest story by far in automatic metalworking in 1960 is in the application of tape controls to turning processes. After Jones & Lamson's introduction of a tape controlled turret lathe at the 1955 Exposition, little further effort was expended in this country to get practical equipment in users' hands. Now, J&L has available a highly refined numerically controlled lathe, for which Boeing has developed an IBM computer program aimed at solving the tool collision problem inherent in all multislide turret machines. In addition, Warner & Swazey and Gisholt have completed lathes which differ from conventional machines to such an extent that they are practically hybrids. Both feature continuous path control in four axes making possible unheard of feats in metalworking, such as the simultaneous finishing of interior and exterior surfaces of thin conical shells.

Unresolved questions

Now that the control engineers have finished their seven-day-a-week efforts to get their new machines before the public, they must wait to see what effects their work will have. It is anyone's guess as to whether or not the metalworking industry will react immediately and match the headlong plunge of the machine tool builders with a storm of purchase orders. The second big question concerns reliability, which in systems to date has been something less than perfect. If tape machines go onto the production floor in the hoped-for numbers, the reliability of tape controls in particular (and perhaps of complex industrial controls in general) is destined for a severe trial.

Another stimulating point of conjecture concerns what control engineers will find as they leave their own display areas and begin peering into the control cabinets of competitors. A massive, crash design effort such as this has been for the machine tool industry can seldom be carried out without some degree of hasty improvisation—and possibly infringement. The intriguing prospect of what could happen is summed up humorously by one control engineer: "After the show, watch the law suits start!"

DRILLING AND BORING MACHINES

LAPOINTE-NORDEN

The Lapointe Machine Tool Co. has developed a tape controlled Universal Hole Positioner having a 57-in. diam rotary table mounted on a cross-slide. The machine is of double column design with a power operated elevator for the spindle cross rail. Spindle has capacity for ¾-in. holes in 1-in. stainless steel. The maximum clearance between spindle nose and the table top in the full forward position is 48 in. With tape control of table and cross rail, the machine can automatically drill, tap, ream, or bore any hole pattern up to a maximum 60-in. bolt circle. It is also capable of scallop, rotary, face, or end milling by operating spindle and table through automatic fixed-increment indexing or pushbutton control.

The two-axis control is the analog version of Norden's numerical system, which employs linear-output synchros

(Decasyns) for feedback. These synchros are coupled to the precision worm and gear drive mechanisms and produce sawtooth signals rather than the usual sine waves, which are indicative of table position. Numerical input is through either standard 1-in. punched tape or banks of selector switches on the panel. Table index and spindle traverse are powered by 90-watt servomotors for tape control and by separate dc gear motors for the other control modes. Table speed is 200 deg per min, while the cross rail moves at 150 in. per min. Indexing accuracy is plus or minus 6 sec of arc.

BURG-HUGHES

Burg Tool Co., which to date has probably sold more numerically controlled machines than any other firm, and Hughes Products have teamed up on the design of the latest version of the Burgmaster turret drill press, Figure 1. Feature of the development is the addition of the tape control of spindle depth to the usual X and Y table positioning. For the latter the control makes use of the standard Hughes incremental system announced last year. Tape data presets a transistorized flip-flop register for each axis. Then table movement begins, continuing until the stream of pulses fed back from photoelectric choppers has counted the register down to zero. For the Z-axis control, however, Hughes has incorporated a magnetic scale for position determination.

The magnetic scale transducer offers about the same accuracy of measurement as the photoelectric choppers, but at less cost. The transducer consists of a series of etched lines on a 14-in. long metal bar. A magnetic detector, consisting of two U-shaped Permalloy loops in a ferrite block, rides on the bar. Its permeability varies as it moves across the lines so that an ac output with peaks occurring at 0.002-in. intervals is obtained. To increase resolution to 0.001 in., Hughes employs two such detectors, one trailing the other by 90 electrical deg. This arrangement also makes the transducer direction sensitive.

The Z-axis control incorporates two electronic counters, one of which is preset for the total depth that the spindle is to move. The second counter determines the distance that the spindle moves at full rate of feed before switching to a lower rate. The dual counters make possible extremely flexible programs of spindle movement including rapid approach of tool to the work, a slower feed into the hole, a creep stage as full depth is neared, dwell at the bottom of the hole for a finishing operation, rapid retract with no dwell, and retract at full feed rate.

The complete three-axis control for the Burgmaster costs approximately $24,000. This figure includes a control console, tape reader, measuring transducer, and two dc drives.

SIBLEY—MICRO-PATH

In contrast to the headlong plunge of most drill manufacturers into tape control, at least one builder is taking a more moderate approach. The Sibley Machine and Foundry Corp. is exhibiting an entirely new drilling machine equipped with a Model 2A two-axis positioning table manufactured by Micro-Path, Inc. The control has decidedly limited flexibility—but cost is very low (about $10,000 including table).

The machine features a 40-in. swing made possible by a massive cast column specially stiffened to permit outboard mounting of the spindle. A 3-hp drive motor provides 16 spindle speeds through a gear box.

The Micro-Path system is a type of record-playback control that uses steel tape stretched along each axis of the table as the recording medium. Initially the table is moved manually to the required hole position. At each position a solenoid-operated punch indents the tape. During subsequent operations, precision switches sense the indentations and send a signal to the control relays each time a hole location is reached.

While the system provides accurate control of position, it relies extensively on manual control for all auxiliary operations. Of particular interest is the way that the standard table controls are supplemented to improve versatility. Sibley equips the machine with a special control panel built into the column. The panel contains a window through which the operator views a line of instructions carried on a continuous roll of 8-in. wide paper tape. These instructions include operation number, table position, type of tool, directions of the next movement, and required speeds and feeds. In addition to the printed messages, spaces on the line are colored in conformance with the signal lights mounted above the viewing opening. By comparing the pattern of lights with the colored spaces, the operator can determine whether or not the machine cycle is proceeding according to plan.

CLEEREMAN-ALLEN BRADLEY

A layout drilling machine made by Cleereman Machine Co. is the first application of Allen-Bradley's new three-axis point to point positioning system. The control is completely transistorized, except for the buffer storage and command-voltage generating sections, which employ electromagnetic relays. Position feedback devices include synchros geared to the leadscrews for all axes plus Inductosyn scales for X and Y motions. Dc

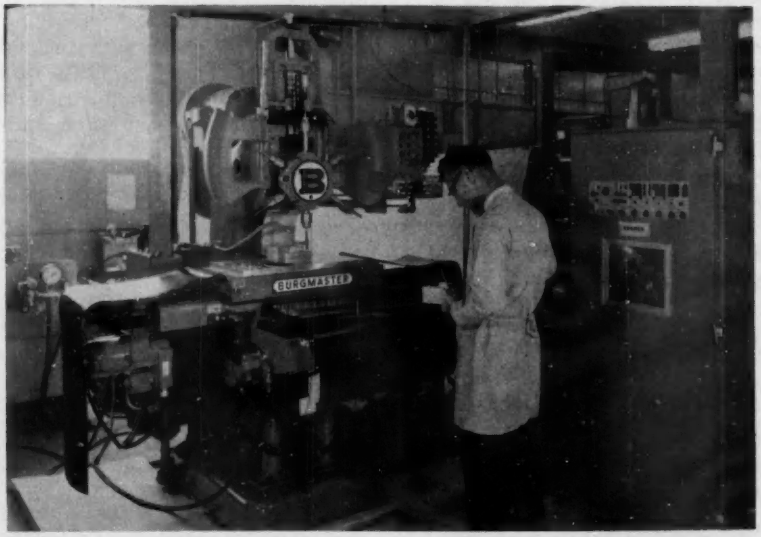

FIG. 1. Turret drill is first application of Hughes three-axis tape control.

adjustable speed drives power the X and Y movements, while the vertical motions are clutch controlled.

GIDDINGS & LEWIS

G&L comes to the Exposition with several new machines in the drilling and boring and the milling classes plus a brand new point-to-point positioning system. Key feature of the latter is that it is a universal package as far as G&L machines are concerned, capable of feeding continuous servo drives for high accuracy, moderate load systems; clutch-type drives having independent X and Y motors for powering heavy milling cuts; and dependent clutch servos where a single drive motor handles both X and Y motions.

The No. 3 jig borer and milling machine picture in Figure 2, for example, is equipped with two-axis tape control with a dependent clutch drive. Input is standard 1-in. punched tape or 10-position dials on the control panel. On some of G&L's biggest machines, such as the Kaukauna horizontals, the control panel has been relocated from the floor cabinet to the elevating platform on which the operator stands. Saddle depth can be regulated by means of a drum with 12 adjustable stops, which is indexed from the tape. Another featured machine is a Cincinnati Bickford drill with a two-axis positioning table, Figure 3. Although the table control is the standard G&L system, it feeds into independent magnetic amplifiers and 100-watt Diehl servomotors. Separate 3-hp ac motors are clutched in for rapid tranverse, an extremely high 360 in. per min. Operator controls include full-range zero offset adjustment and an axis reversing switch which permits "flipping" tape data for mirror-image parts.

The new control uses the Inductosyn linear resolver plus four other conventional resolvers for multispeed feedback. In positioning, control is switched progressively from the coarse resolver through the medium units to the scale. For continuous servo drives, conventional nulling techniques are employed to eliminate the error signals. In the independent clutch-motor type drives, the resolver-selecting switches actuate combinations of control clutches for multiple gear trains, establishing a five-step slowdown pattern. The most ingenious capability of the system is its control of these clutches when only one motor is used and it is required to position different distances in each axis. A logical switching network solves this problem by delaying motion in the axis with the smaller position error until the motion along the other axis enters the same speed range.*

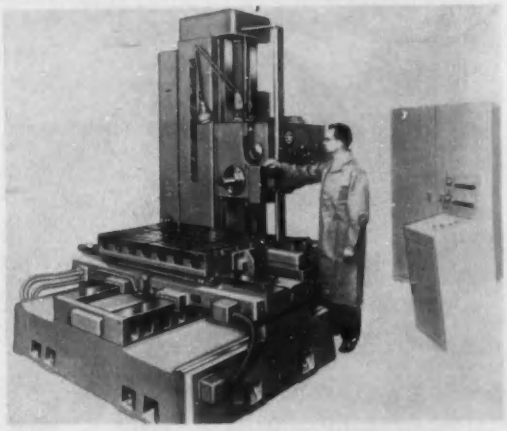

FIG. 2. Dual-purpose G&L control is suited for use with either fast response clutch servos or continuous drives for high-accuracy machines such as this horizontal jig borer.

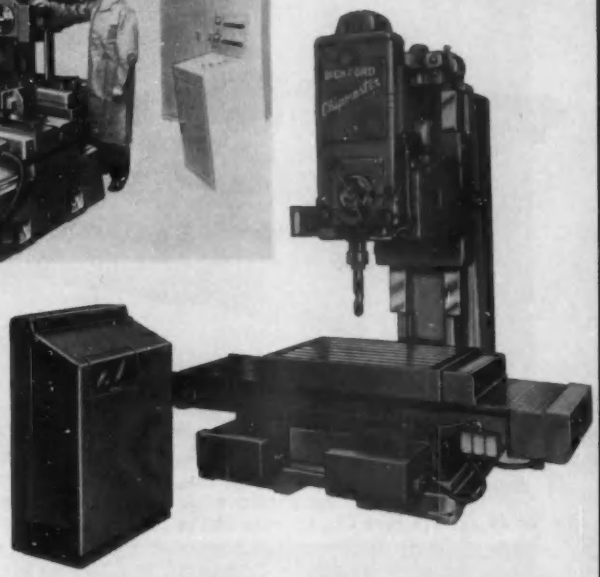

FIG. 3. Tape controlled two-axis positioning table is capable of 360 in. per min traverse speed.

FARRAND-RELIANCE

Continuing to exploit the highly successful Inductosyn scale, Farrand Controls, Inc. has completely overhauled its original control system. Transistors now perform all amplifying and switching functions except address and number distribution which still require stepping switches. Modular plug-in construction is used throughout, even for the computing transformers that supply the sine-cosine command voltages. Steppers are also mounted on easily removed modules which include the Nixie tubes used for digital display. The entire control for three axes measures only 24 x 24 x 38 in.

The new system incorporates two important contributions to the numerical control art. The first is a new tape reader which converts binary-coded decimal tape data into straight decimal directly. This eliminates the need for the extensive switching-matrix decoder usually needed. Decoding is done mechanically by a crossbar-like system of levers actuated by the reading fingers. The tape employs a tab sequential format for simple programming. Commands for X, Y, auxilaries, etc. appear in a fixed order, so that the programmer need only depress the Tab key on the tape punch to separate the commands.

The most important Farrand announcement concerns the development of a multispeed Inductosyn scale, wherein two coarser windings are superimposed on the fine pattern. Heretofore, of course, the Inductosyn resolver measured movements less than 0.05 in. and two or more conventional resolvers had to be geared to each axis to bring the moving member within the range of the scale.

The Reliance Electric & Engineering Co. is marketing a system substantially identical to that just described. First application is on an Allen vertical drilling machine having 16 in. of controlled movements in the X and Y table axes. The three-axis system also programs the rapid traverse and downfeed movements of the spindle. Total spindle travel is 10 in. and resolution is 0.01 in. The resolution in X and Y is 0.001 in.

A second Reliance system is employed on a Lahr hexagonal turret drilling machine, Figure 4. The table is stationary, but the turret traverses 90 in. in the longitudinal axis and 20 in. in the transverse axis. Dc drive motors position the head along the X and Y axes at speeds up to 150 in.

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* *For a full description of the circuitry involved, see "Single Time-Shared Drive Positions Two Axes" by George W. Younkin,* CONTROL ENGINEERING, *August 1960.*

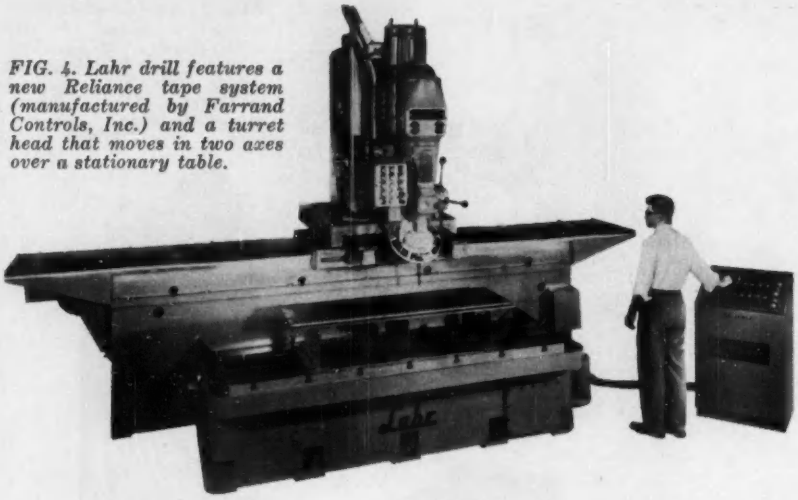


FIG. 4. Lahr drill features a new Reliance tape system (manufactured by Farrand Controls, Inc.) and a turret head that moves in two axes over a stationary table.

per min. from tape commands. Tool selection is also programmed.

HEALD

A universal indexing fixture made by Heald Machine Co. features dial-in setup of index positions. The control makes it possible to divide 360 deg of fixture rotation into any number of equal increments up to 99. A torque motor drives the table, whose shaft carries a photoelectric encoder. As the shaft rotates, a moire fringe pattern interrupts a light beam causing pulses to be fed back to a transistorized counter. This counter is preset with a binary-coded octal number representing the number of feedback pulses equivalent to the desired increment of index. The octal system provides adequate capacity for the highest counts possible in this application and, in addition, permits use of simpler circuits than those needed for full decimal counters. When he wishes to arrange the controls for a particular number of indexes per revolution, the operator refers to a chart which provides counter settings equivalent to each number from 10 to 99. He then turns selector switches on the control to this equivalent.

W. F. & JOHN BARNES-SQUARE D

Two control developments of W. F. & John Barnes Co. are scheduled for introduction at Exposition time. The first is a circuit for "rejuvenating" defective limit switches. A common fault of limit switches exposed to cutting oils and coolants is deterioration of open circuit resistance. Metal filings in solution actually "print" invisible paths for leakage current. Present practice is to discard switches when leakage current is detected. The Barnes answer to this problem is to put a packaged electrical network in tandem with each limit switch. This close differential can recognize the difference between closed-contact and open-circuit resistance even when leakage currents are appreciable. Thus limit switch life is prolonged.

The second Barnes accomplishment is a feedback transducer for numerical positioning systems. Square D Co. has been licensed to make the scale and apparently based the design of a new tape control system on its unique properties. Figure 5A is a schematic diagram of an elementary transducer which consists, in essence, of a long, hollow tubular core carrying a primary winding. The extreme ends of the coil are connected to the same side of an ac line. The opposite side of the line is tapped into the center tap on the primary. The transducer secondary consists of a shorter helical coil wound on a hollow core which moves concentrically over the primary. As the secondary slides over the primary, its output voltage varies as shown and undergoes a reversal in phase at the midpoint of the primary.

Because a device with only one null point is not very useful in position measurement, the practical version of this scale actually has many points. In the version of Figure 5B, the ends of the primary coil are again connected to one side of the line. The second side of the line is connected through a selector to taps located precisely 1 in. apart. Thus the selector switch serves as a coarse positioning control since it shifts the null to any one of the 1-in. markers. As it moves over the chosen tap, the output voltage of the secondary coil behaves as shown in Figure 5C. The amplitude and phase of this voltage can be used for control of fine positioning to a resolution of 0.001 in.

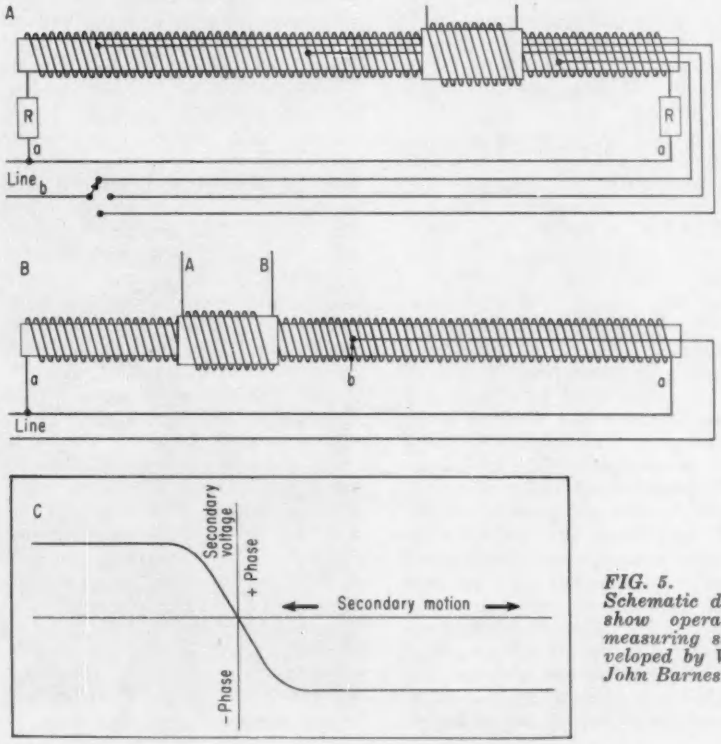


FIG. 5. Schematic drawings show operation of measuring scale developed by W. F. & John Barnes Co.

PRESSES

DENISON

A hydraulic servo has reduced the many adjustments and stop settings usually associated with press setup operations to the changing of a single cam. This feature distinguishes the new 25-ton metalworking press introduced by Denison Engineering Div. Rate, length of stroke, bottoming point, and speedstroke profile are all controlled by means of the servo.

The press ram is driven directly by a double acting hydraulic cylinder mounted at the top of the structure. A servovalve controls the flow of oil into the main cylinder. The servovalve spool is linked to a cam follower that rides in contact with a motor driven cam. As the valve spool is stroked back and forth by the cam follower, the action of the main ram exactly duplicates that of the spool. The press speed is adjusted by changing the speed of a small electric motor driving the camshaft. The absence of dog operated valves on the ram and the stiffness of the hydraulic servo combine to raise the speed capabilities to 600 hits per minute.

BEATTY

Although the press or punch field is not considered a prime market by builders of numerical control systems, an application of a tape unit has been made to a 200-ton guillotine beam punch with good results. Beatty Machine and Mfg. Co. is now producing a tape controlled spacing table for feeding huge I-beams through the machines that punch rivet holes into the webs and flanges. The beams ride on conveyor wheels and are pulled through the punch by hydraulic clamps attached to a motor driven carriage, Figure 6. Normally the operator spots the beam under the punch by reading a steel scale mounted along the bed of the runout table and pushing the carriage start-stop buttons. The new spacer table is equipped with a GE single axis control, with dial and punched tape input, that positions the beams automatically. The tape can also be used to actuate solenoid valves and air cylinders that select any or all of the punching fixtures mounted on the machine crosswise to the beam. This, in effect, provides for locating holes in both X and Y so that any pattern can be produced.

Certain characteristics of the table make it a challenging application for numerical control. First, it is required to handle beams as long as 50 ft. And the material weight varies from a few pounds per foot up to 300 or more lb per ft. Offsetting these wide shifts in load are the modest accuracy requirements of plus or minus $\frac{1}{8}$ in. A 3-hp Ward Leonard drive powers the carriage at 53 ft per min.

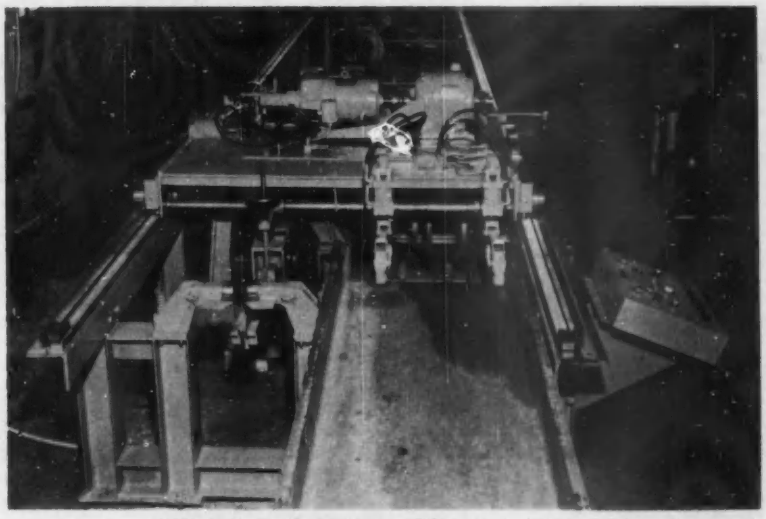


FIG. 6. One-axis system positions 50-ft I-beam under hole punch.

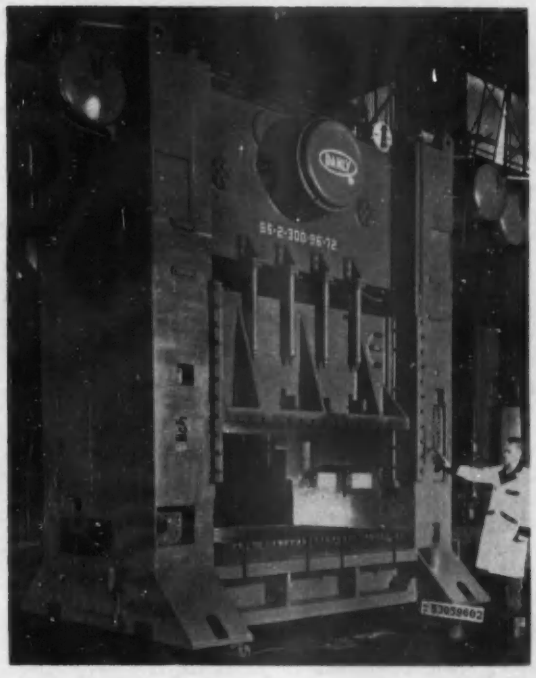


FIG. 7. Linear differential transformers and hydraulic cylinders eliminate the dangers of overloading in this mechanical press.

DANLY

Builders of the big stamping presses, such as that in Figure 7 manufactured by Danly Machine Specialties, Inc., have added considerably to the control content of their machines. Danly has adopted servocontrol for positioning the slide over the press bed during setup and die changes. A potentiometer geared into the elevating mechanism feeds back signals on slide position to a transistorized error amplifier. Output of the latter either energizes a relay for a constant speed positioning motor or regulates the

output of a rectifier panel for an adjustable-speed drive. Accuracy of the system is plus or minus 0.004 in. The same press is equipped with hydraulic overload protection to eliminate one of the most prominent causes of machine and die failure. The load regulator consists of hydraulic cylinders interposed between the mechanical cranking system and the slide. The cylinders transmit all working forces to the die and are filled with oil under carefully regulated pressure. When the limits of the machine are exceeded, pressure switches act to dump the hydraulic pressure and stop the operation of the machine.

Danly has also developed a load indicator for use in connection with the overload protection. The indicator consists of a linear differential transformer which is tied to the force transmitting sections of the press. The transformer output voltage, which is proportional to the strain in the structural members, is transmitted to a bank of 10 neon lamps, each of which is biased by a different voltage. As transformer voltage rises, it progressively overcomes the bias on one lamp at a time. Each lamp represents a range of loads so that the bank of lamps serves as a graphic indicator of load conditions at any given moment.

Proximity switches have been incorporated in the control system for quick die change presses to prevent operation of the machine if the die carrier is not properly seated. The switches are of Danly's own design, are energized directly from a 60-cycle supply, and produce an output when the carrier is brought within 0.01 in. of their surface. Any tilt in the bolster due to chips, dirt, or other interference prevents at least one of the two proximity switches from delivering an output voltage to the interlocking relay, and the press cannot be started.

The machine logic features completely transistorized circuits which have sufficient output ($\frac{1}{4}$ amp) to directly energize solenoid air valves for the main clutch. The transistorized logic includes the interlocking circuits plus a zero-speed detector, which is used to signal jamming of the press or to trigger nonrepeat controls. The zero-speed device comprises a toothed wheel rotating next to an inductive pickup. The pickup, which is sensitive to as low as 3 rpm, delivers amplified pulses to an interlocking relay.

Danly's 110-ton OB1 press has been equipped with a new static speed control employing silicon controlled rectifiers. The drive for this press is a constant speed ac motor working through an eddy-current clutch. The design of this drive started with magamp controlled selenium rectifiers some years ago and progressed to silicon rectifiers and now to the newest types. Two 4.7-amp silicon controlled rectifiers are connected in a full-wave bridge configuration and triggered by a Magnetics, Inc. packaged control.

WIEDEMANN-SPERRY

First of a line of turret punch presses designed specifically for numerical control is Wiedemann Machine Co.'s Model A-15, Figure 8. The new 15-ton unit can consistently maintain a peak rate of 60 hits per min under tape control in contrast to the average rate of 30 to 35 hits per min achieved with manual control. To withstand the increased duty cycles involved and to provide the mechanical stiffness needed for high performance servos, the machine is of massive construction, weighing three times as much as an equivalent manually controlled unit. The rapid traverse rate of the worktable is 600 in. per min in each axis and is produced by hydraulic cylinders controlled by Sperry servovalves. The cylinders are double ended, with rams extending from each side.

Positioning in the Y or transverse axis involves movement of a high-inertia table. To provide the 600 in. per min traverse rate in this axis, the servovalve is paralleled by a four-way valve. For rapid traverse both valves are opened full; then as setpoint is approached, the four-way valve closes and the servovalve assumes proportional control. Acceleration and deceleration rates can be adjusted by means of pressure relief valves in the feed and exhaust lines. The servovalves are of the rotary type, having torque motors directly connected to the spindles. The absence of intervening linkages makes the valve less sensitive to temperature variations and machine vibrations.

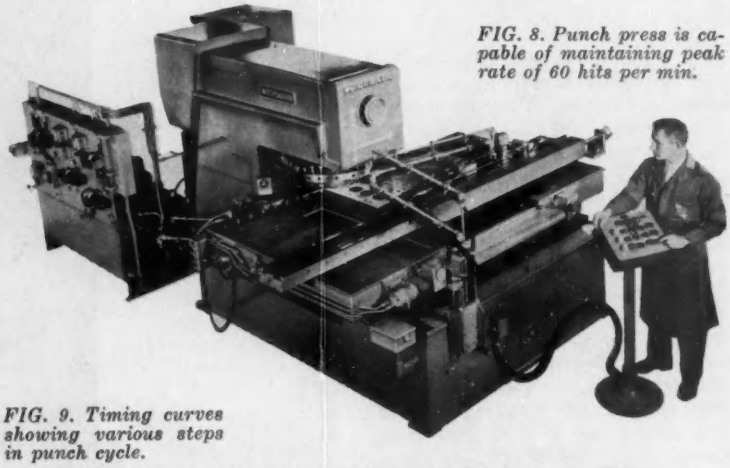
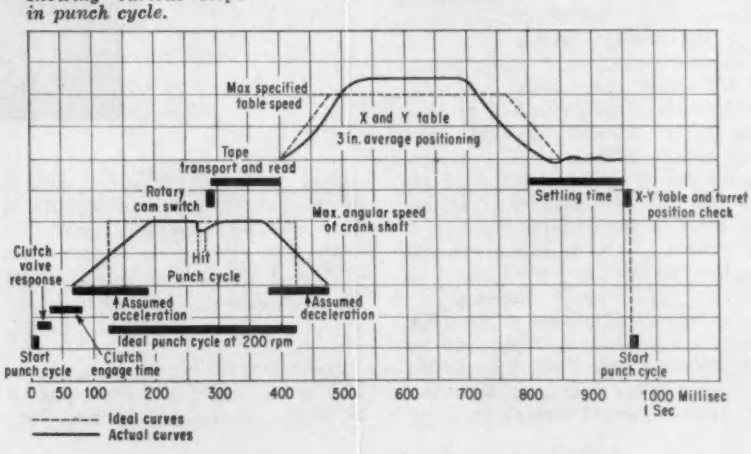


FIG. 8. Punch press is capable of maintaining peak rate of 60 hits per min.

FIG. 9. Timing curves showing various steps in punch cycle.



A Sperry two-axis system controls X and Y table movements as well as all auxiliary functions including indexing the 32-station turret. The feedback instrumentation consists of coarse resolvers and a linear scale for fine positioning. The scale is composed of a glass-mica stator and slider on which a series of fine lines are plated in the form of elongated hair pin coils. The two elements of the scale serve as the primary and secondary of a transformer; when the slider is energized by an ac signal, the stator output is a voltage that varies from maximum to null depending on the relative positions of slider and stator.

The main problem encountered in automating the punch press is the short time (1 sec) allowed for each punch cycle, which must include the many segments depicted in Figure 9. One of the main advantages of the Sperry system for this particular application is that the tape mechanism reads a whole block of data at one time rather than a line at a time. This makes possible the 100-millisec readout time shown without the use of buffer storage. A cam coupled to the pneumatic-clutch controlled cranking mechanism triggers the reader for transfer and readout as soon as a hole has been punched and the die begins to withdraw from the work. Thus readout takes place as the die is being withdrawn to top dead center. Another time-saving expedient is a simple cam and relay logic arrangement that programs the turret to take always the shortest route to the tool called for by the tape commands.

TOOL-CHANGING MACHINES

NATCO

The National Automatic Tool Co., Inc. is entering the field of multiple purpose tool-changing machines with two new models. The first is the feature-loaded G. S. P.-Matic, Figure 10, which Natco distributes for Ateliers, G. S. P. of France. Its attractions include two automatic tool changers, two working spindles, and three-axis tape control. The machine consists essentially of a spindle head sliding vertically on a massive column and a 45 x 26 in. table designed for transverse and longitudinal movements of 24 and 38 in., respectively. The head carries a heavy duty main spindle as well as a high speed spindle for operations on smaller holes. The spindles are driven by an 8-hp motor through a 16-speed gearset. The capabilities of the machine include milling, drilling, tapping, and precision boring.

Punched 35-mm movie film controls X, Y, and Z movements and all auxiliary functions including tool changing and spindle selection. In accomplishing the latter the system automatically compensates for the 8-in. center-to-center distance between the axes of the heavy duty and high speed spindles. The 10-channel straight-decimal tape code is scanned photoelectrically one line at a time and the resulting transistor-amplified signals used to energize logic relays. Manual controls on the main panel permit the operator to modify tape data for all three axes to compensate for tool wear, deflection, etc. Compensation is limited to the three least significant digits for any given position. The measurement of table position and tool depth is by means of turret-type gage rods, such as those used in certain types of jig borers for many years. Command data determines the selection and stacking of combinations of rods to provide the desired position. The table and spindle are then driven against these rigid stops so that system accuracy is completely independent of the leadscrews.

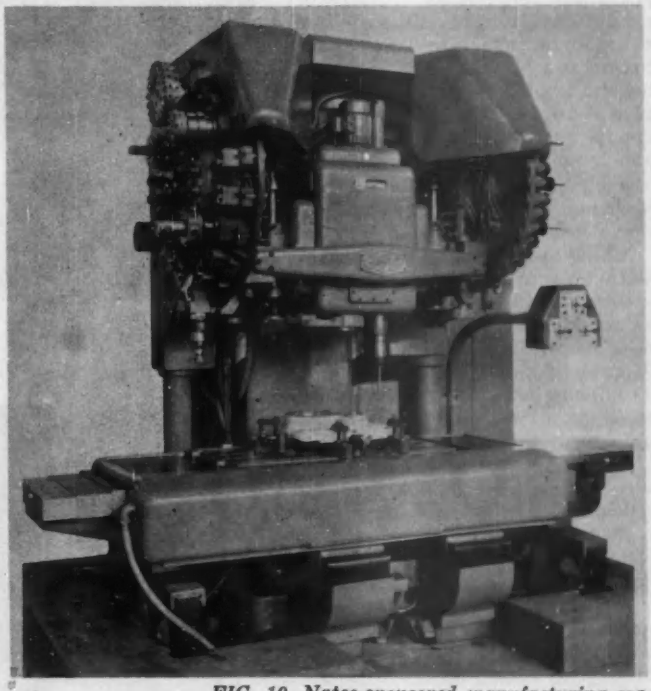


FIG. 10. Natco-sponsored manufacturing machine has two spindles and two tool changers.

Mounted on each side of the machine is a drum-type tool carrier. The left hand unit contains up to 18 tools for the heavy duty spindle, and the right hand carrier stores as many as 36 tools for the high speed spindle. Tools are stored in the horizontal position. When a tool change is to be effected, the appropriate carrier indexes the desired tool until it is adjacent to the spindle in use. The tool then drops into a vertical position, and an oscillating changer mechanism simultaneously grasps the new and the used tools. Then the changer reverses direction, interchanging the tools in the spindle and carrier.

Natco also is introducing a multipurpose "tool-presenting" vertical spindle machine of its own design. The tool presenter consists of a magazine that rotates under tape commands to bring a desired tool close to the operator's station. The operator himself

performs the actual tool change. Later versions of this machine will be available with a tool changer.

The 3-hp spindle drive provides a speed range of 50 to 3,000 rpm in 18 geometrically progressive steps. The head is traversed by a hydraulic motor through a precision ballnut screw. Similar drives are used for the 24 x 36 in. table movements. The three-axis tape control system is made by Natco and employs coded disc feedback and electromagnetic relay logic.

LUCAS—GE

Another new form of hybrid tool-changing machine is the Lucas Versa-Tronic, Figure 11, which is a combination milling, drilling, and boring machine. In design it resembles somewhat the conventional planer-type vertical spindle miller, although it is not nearly so large. The Versa-Tronic consists of a 24-ft bedway along which the table slides. Two columns attached to the bedway support the spindle crossslide. The 4-in. diam spindle provides sufficient capacity for face milling cutters up to 14-in. diam. Maximum workpiece size is 132 in. long, 78 in. wide, and 72 in. high.

A GE three-axis positioning system controls longitudinal table travel, crosswise travel of the spindle head, and spindle depth. The system employs synchro feedback and a single 20-hp ac servo drive motor coupled to all motions through electric clutches. Rapid traverse is 75 in. per min in all three axes.

The automatic tool changer uses a a pigeon-hole magazine mounted directly on the machine table or attached to its side. As many as 84 tools in the vertical position can be stored in this magazine. No tool carrying arms or mechanical linkages are required. Instead, tool location and pickup are accomplished through the three standard motions under tape control. To select a tool, the X and Y coordinates of the tool in the magazine are programmed onto the tape so the spindle moves over this point of pickup.

An orienting control built into the spindle head causes the spindle to always stop in the same angular position, so drive keys in the spindle line up with keyways in the tools. Keying between the tool and magazine maintains each tool in the proper angular position to match the spindle orientation. The tool is secured by a power tool lock and ejector built into the spindle. This arrangement consists of a draw collet specially designed to fit adapters on the tools. These adapters are screwed into the standard threaded hole in the regular machine taper arbor on each tool. The collet is cycled open to receive the tool and closed to wedge-lock it in place for use in subsequent operations.

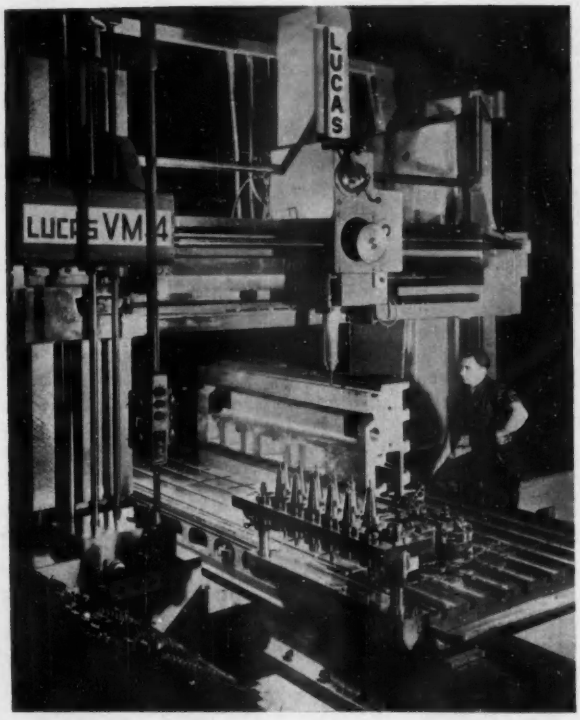


FIG. 11. Normal positioning controls serve the tool changer as well in this Lucas hybrid.

The cost of the machine complete with tool changer and tape controls is about $150,000.

KEARNEY & TRECKER

As originator of the "manufacturing machine" concept, Kearney &

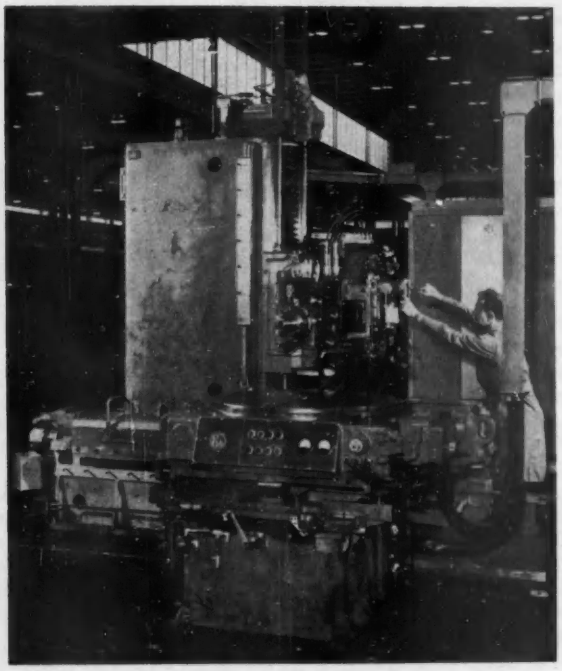


FIG. 12. Pratt & Whitney tape controlled table wedded to standard Milwaukee-Matic.

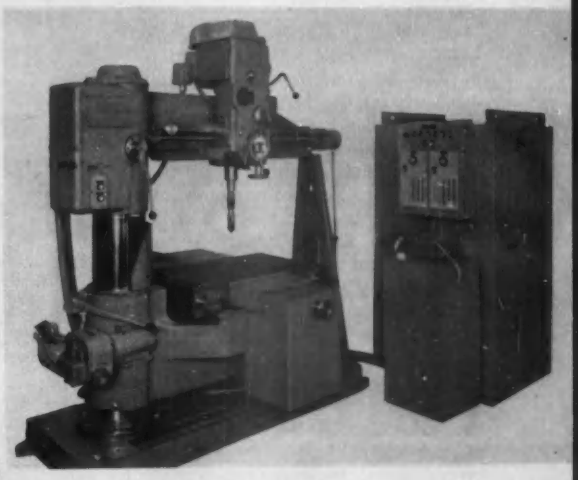
Trecker Corp. is continuing its efforts in this field with the introduction of the Milwaukee-Matic Model III. The design of the new machine is similar to that of the Milwaukee-Matic II which was made available about two years ago but can handle workpieces as large as a 3-ft cube. The earlier machine could accommodate only an 18-in. cube. A GE positioning system controls the movements of the column (horizontal), saddle (vertical), table (transverse) and all auxiliary functions.

The automatic tool changer and a 360-position indexing table are standard equipment. The tool magazine stores the same number (30) of individual tools as in the smaller machine, but their maximum permissible size is now 13 in. long, 6 in. in diam in contrast to the earlier limits of 7½ in. long, 2⅝ in. in diam. Tools are identified for selection by means of coded rings on the tool holders. A total of 961 different code patterns are available. The double acting tool change mechanism simultaneously inserts the new tool into the machine spindle and returns the used tool to the magazine. Tool transfer is completed in a few seconds.

All three axes of the machine are driven by high performance hydraulic servomotors through hardened and ground gears fixed to recirculating ballnut leadscrews. A special feature of the numerical control system enables the machine to perform approximate profiling operations in the X-Y plane (column and saddle). The control uses a limited form of circular and linear interpolation to establish cutter paths along arcs and slopes. Arcs can be generated with radii ranging from 0.1 to 99 in. in increments of 0.1 in. Angles are approximated within plus or minus 1 deg of true slope. The Inductosyn scale is retained as the fine feedback transducer. A pallet shuttle can be provided for transferring workpieces into and out of the machine automatically. An additional tape reader is required for this materials handling feature.

Besides the Model III machine, K&T has developed a modified version of the smaller Milwaukee-Matic that incorporates a Pratt & Whitney rotary table, Figure 12. The 42-in. table employs the P&W standard numerical control system and Electrolimit gage blocks for measuring angular position. The P&W controls are integrated into the GE controls for the other axes and operate from the same tape reader.

FIG. 14.
High-precision drill uses two-axis G.E. system.



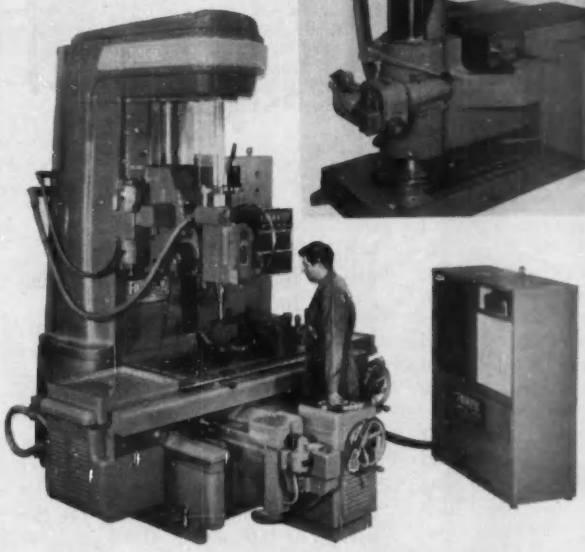


FIG. 13.
Fosdick's three-axis tape controlled jig borer is available with 100-tool automatic changer.

FOSDICK

Almost four years ago The Fosdick Machine Tool Co. initiated development of the first fully automated jig borer, featuring tape control of table position and spindle depth plus automatic tool changing. Their new version of that machine (Model 54p, Figure 13) retains all of these features but uses radically different means to accomplish them. Fosdick's turreted gage rods are still employed for feedback of X and Y table position, but punched tape plus a North Electric crossbar storage and decoding network replace the IBM card reader. For depth control two gage-rod assemblies (one for measuring rapid traverse distance, the other for depth of feed) have been added to the spindle. This arrangement substitutes for the original sonic detector (which controlled rapid traverse by determining when tool contacted the work) and the photoelectric digitizer and counting system (for gaging feed depth). To compensate for changes up to 1 in. in tool length, banks of potentiometers (one for each tool used during the machining cycle) are provided on the control panel for manual adjustment of depth. When a tool is chosen by the tape, the appropriate input potentiometer is connected to a separate potentiometer-feedback servoloop. The servomotor adjusts the position of a rod that forces the gage rods against the trip switch.

Perhaps the greatest revisions have taken place in the tool changer. This is now a separate hydraulically powered assembly mounted adjacent to the jig borer. A semicircular array of pigeon-holes (five high and as many as 20 across) holds the tools in contrast to the vertical-axis turret first designed. Maximum tool capacity is 100, up from 30.

The other machines exhibited by this firm for the September showing include a jig grinder with a two-axis Fosdick control and a radial layout drilling machine, Figure 14, having two-axis GE tape control. In addition, Fosdick announces its entry into the turret-drill competition with a unit having the extraordinary turret capacity of 32 tools. The machine has a vertical turret axis.

LATHES

JONES & LAMSON

At the 1955 Exposition, Jones and Lamson Machine Co. exhibited one of the few numerically controlled machines on the floor—and the only tape controlled turret lathe. From this early start, J&L has progressed to a highly refined machine, Figure 15, which makes parts completely automatically with preset tools. The lathe is equipped with a hexagonal turret plus front and rear square turrets. The crossslide, which carries the two square turrets, has a total travel of 13 in. Both the hex head saddle and the crosslide carriage are capable of 24-in. movement along the bedway. All three movements can be positioned from the J&L-designed two-axis numerical control system, any two simultaneously. Tape commands also control the rotation of the turrets, the feeding of bar stock through the spindle, and the number of pieces of a given type that are produced.

Four-speed synchro clusters geared to the leadscrew for each axis are used for position measurement. These leadscrews are of instrument grade since they are not required to transmit thrust to the slides. The only load imposed on the screws is the shifting of the spools of servovalves, which control the hydraulic cylinders powering the machine motions. The logical sections of the system have been reduced in complexity to such an extent that the use of reliable but costly mercury-wetted contact relays is practical. The null detectors have been simplified to combinations of transistors and relays in tandem.

The spindle drive is a 30-hp ac motor. The hydraulic system for positioning the carriage, crosslide, and saddle operates at 100 psi, while 500-psi oil is used to provide secure tool clamping and positive turret indexing. J&L has abandoned the 4-in., 32-channel punched tape originally used for standard 1-in., eight-channel tape.

PRATT & WHITNEY

To provide some of the advantages of tape control at minimum cost, Pratt & Whitney Co., Inc. has included a modest form of system on the new Potter & Johnson automatic turret lathe, Figure 6. Formerly, this machine featured a dog-type drum synchronized with the main drive motor to program feeds and speeds, turret index, clamping, etc. Now this drum has been replaced by a tape reader, which is also synchronized with the main drive. Because it moves continuously, the tape serves as a timing control for all operations.

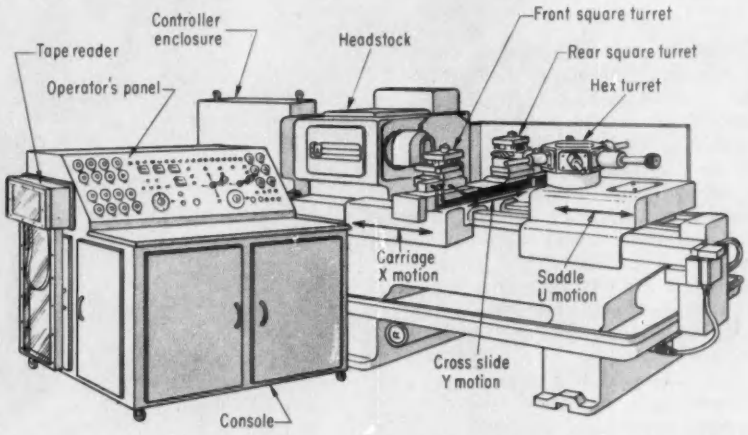


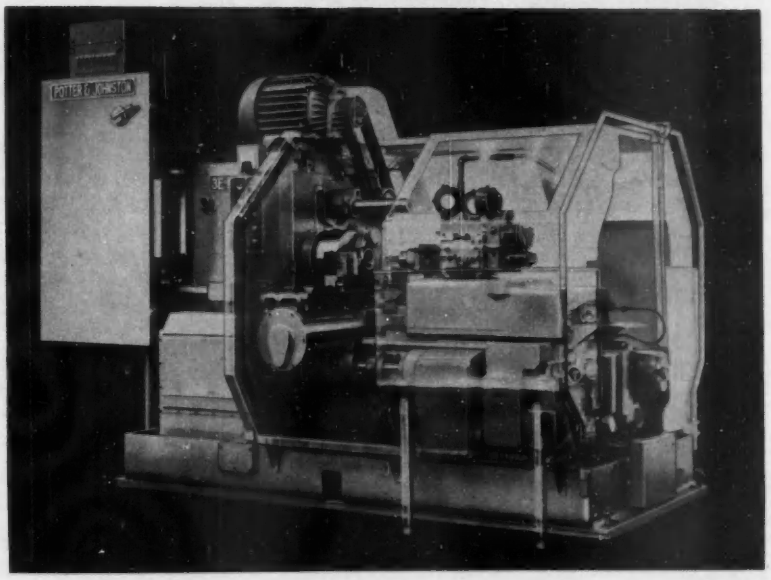
FIG. 15. Sketch of Jones and Lamson turret lathe with three controllable motions.

On each continuous loop of 1-in., eight-channel tape are 600 sprocket holes representing one complete machining cycle. A block of 100 holes is assigned to the operations performed by each of the turret faces. As a block enters the reader, the turret is indexed to the proper face and the machining conditions set up for the cut. The tape also controls positioning of the turret slide to some extent. Although the turret slide always moves back and forth through a fixed distance, it is desired to control the length of the rapid traverse infeed motion before the slide drive is switched into feed. This is easily accomplished because the tape movement is synchronized with the movement of the turret slide. A number of rows in each block are assigned to the slide advance cycle, and by punching an appropriate row, the feed length can be selected.

BULLARD-GE

Regarded in some quarters as the originator of numerical control for machine tools, The Bullard Co. has already tasted the success that fully automatic programming can bring. When the jet engine program was at its peak, Bullard turned out Man-Au-

FIG. 16. Punched tape has been substituted for dog-type drum in Potter & Johnston lathe.



Trol-equipped vertical turret lathes by the hundreds. Man-Au-Trol's resemblance to numerically controlled closed-loop servo drives can be seen from Figure 17. The drums shown, which are geared into the vertical and horizontal feedscrews for the turret head, consist of series of cams, each of which can be adjusted to control the length of one movement of the head. Cam switches energize solenoid valves to clutch or declutch the leadscrew drives. Two drums are assigned to each axis, one for coarse and one for fine positioning. In addition to the position drums, there are two program drums that index to control all steps in a machining cycle, including initiating auxiliary functions and selecting individual cam discs on the position drums for controlling individual steps.

Bullard's newest version of the vertical turret lathe features a punched tape system to replace the drum-and-cam programmer. The control is a GE two-axis system that duplicates the functions of the mechanical programmer. However, syncho feedback is substituted for the positioning cams and flexible punched-tape programming, for the cycle drums, which require considerable setup time.

Bullard has also developed a wide range (0-1,800 rpm) stepless drive for rotating the lathe worktable. The drive consists of a constant speed ac motor and a system of planetary differentials that are clutched in and out under electrohydraulic control to cover fixed portions of the range. The stepless action is provided by a small adjustable speed hydraulic motor coupled to the differential gearing. In any particular portion of the range, the hydraulic motor at first opposes the rotation of the output shaft. As more output speed is called for, the rotation of the hydraulic motor is slowed and then reversed so as to add to the motion of the main shaft.

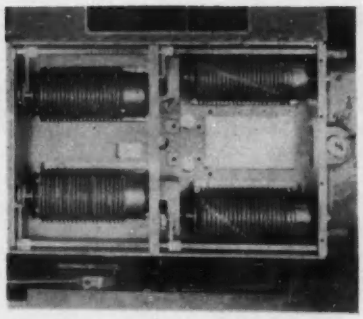


FIG. 17. Programming and positioning drums in Bullards Man-Au-Trol, regarded by some as the forerunner of numerical machine-tool control. Bullard is now offering tape control on newest vertical turret lathes.

WARNER & SWASEY

Probably the most revolutionary machine tool to appear in 1960 is the Warner & Swasey Co.'s Servofeed lathe,* which is available for manual control as well as with record-playback positioning, tape-input positioning, and continuous path control. Although it bears little resemblance to conventional equipment, as can be seen from Figure 18, the machine may be described as a turret lathe with one square and one pentagonal turret. Both turrets operate on crossslides, which are tilted up almost vertically to provide better accessibility and visibility for the operator, superior dynamic performance, and improved chip disposal. The slides move on ways that are parallel to the spindle axis so that there is a total of four axes of motion.

Even in the manual machine the toolslide leadscrews are driven by adjustable speed dc servomotors controlled by high performance loops that include both velocity and current feedback. Synchro driven dials on the manual control panel indicate positions in all four axes. A unique feature of this panel is that it is itself mounted on a slide and can be moved anywhere along the front of the machine to suit the operator.

The positioning control is completely digital. Prior to cutting a particular part on the machine, the complete tape for that part is run through the reader and its information stored in a magnetic core memory. During the operation of the machine, the memory—not the tape—is the source of all control commands. The memory consists of a 96 x 96 array of cores with capacity for 96 separate binary coded instructions each having as many as 96 bits. The feedback transducers geared to the leadscrews are photoelectrically read coded discs.

The use of the core memory makes it possible to provide the record-playback feature. At each step in the manual the cycle, signals from the position transducers and the operator's controls are dumped into the memory directly, rather than from the tape.

For contouring the control assumes the proportions of a combination absolute-incremental system. The heart of the contouring control is a linear interpolator that converts tape commands relative to distance, direction, and speed to an equivalent stream of pulses. These pulses are used to set a bidirectional counter serving as an error register. Prior to starting a contouring cut, the tool is brought to its zero position under absolute position commands supplied from the core matrix. Then a chain of subsystems, including the error register, digital-to-analog converter, and servoamplifier, energize the leadscrew drives. In this case also, position feedback comes from the same transducers which have the facility of serving both as shaft encoders (for positioning) and pulse generators (for contouring).

FIG. 18. Warner & Swasey Servofeed lathe has control console that can be slid along front of machine.

The tape reader and logic assemblies can serve only one head at a time. If both heads are required to contour simultaneously, two sets of readers and logic must be provided. As in other contouring systems, tape preparation involves the use of a general purpose computer for determining cutter offset and maximum chords. Warner & Swasey has designed an IBM 650 program for this purpose.

Portions of the basic contouring control have also been applied to a standard W&S 4-A turret lathe. The cross-sliding turret head of this machine is now capable of tape controlled contouring along two axes. Tape control is available, too, for standard 1AC single spindle automatics. In this case, however, the system is much less sophisticated. It

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* *A detailed technical description of this machine is contained in the article "Numerical Building Blocks Control Turret Lathe",* CONTROL ENGINEERING, *July 1960.*

consists merely of a tape reader and relay network that serves as a direct replacement for the mechanical program drum usually supplied.

GISHOLT

Credit for applying the widest variety of numerical control systems to turret lathes goes to the Gisholt Machine Co., which has made three completely different combinations available. The first is the standard Fastermatic automatic chucking lathe equipped with a Westinghouse Prodac tape control. The latter handles positioning in one axis plus all programming functions such as tool selection and setting of spindle speed. The Westinghouse system is completely digital with decoding and counting operations handled by transistor NOR packages. For positioning, tape data presets the error register with a count equivalent to the desired motion distance. As the slide is driven toward setpoint, a pulse generator geared to the slide acts to restore the counter setting to zero.

A second Gisholt Fastermatic lathe has been fitted with a three-axis dial-in positioning control manufactured by Specialties, Inc. This system employs a combination of a drum-type programmer and a group of panel dials to establish the machining cycle. The drum carries a series of pre-punched keys such as those shown in Figure 19, which are read photoelectrically as the drum indexes. During setup the operator selects applicable keys from a storage file covering every possible machine function and inserts them into the drum. Position feedback is by means of linear transducers mounted along each of the three axes of motion. The transducer consists of a stainless steel housing and a movable core. The housing contains a number of windings so arranged that as the core —which is composed of alternately north and south magnetic poles— moves through it, a series of four linear voltages is produced. The same pattern of output voltages is repeated every 2 in. The transducer provides both coarse and fine position data.

One dial on the panel is used to control each positioning step; which dial is in control at any given moment is determined by the drum programmer. The dial supplies a coarse signal to a transistorized register which counts the voltage peaks generated by the feedback transducer. Within $\frac{1}{2}$ in. of setpoint, control is switched to the find command. The latter is a voltage delivered by a miniature replica of the feedback transducer, which is mounted behind the control dial. The feed rates of the hydraulically driven tool slides are also controlled by individual dials on the panel. These dials regulate the amount of opening of motor-driven valves.

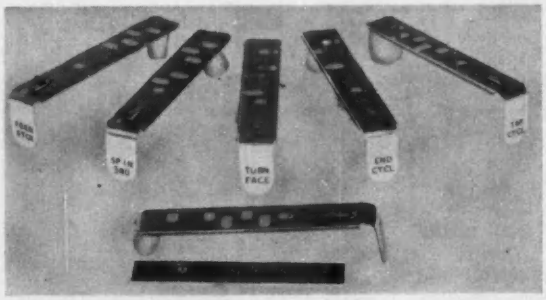


FIG. 19. Programming tabs for numerical control system built by Specialties, Inc.

GISHOLT-FACTROL

Gisholt's third numerically controlled lathe is a brand new machine, Figure 20, with two tool-carrying members: a four-position tool post on a universal tool past carriage and a hexagonal turret head also mounted on a universal carriage. The Factrol system employed on the machine is Gisholt's own and is capable of continuous path and rate control in all four axes simultaneously. It is basically a phase analog control and requires seven-track magnetic tape input. All controls are built into the

FIG. 20. Gisholt lathe is capable of simultaneous contouring in four axes.

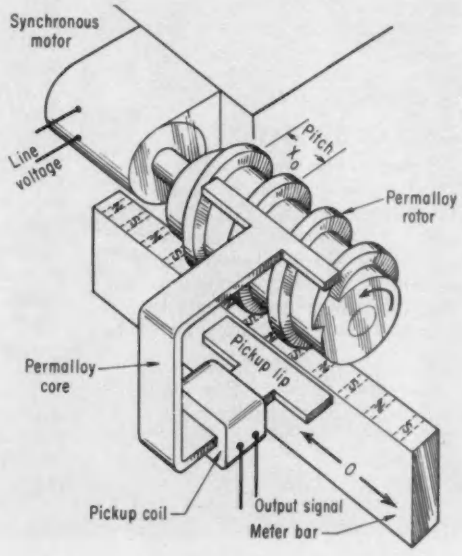


FIG. 21. Schematic of Gisholt's Factrol position-measuring transducer.

machine itself; there are no external cabinets. The tool slides are driven by hydraulic cylinders regulated by servovalves. All electrical and hydraulic connections to the moving members are made through telescoping rigid tubing and manifolds so that no cables or hoses are visible on the operating machine.

Figure 21 is a schematic drawing of the position transducer, which consists of a measuring head mounted on the machine bed and a meter bar attached to the moving member. A synchronous motor drives a scanning screw at a speed of 120 pitches per sec relative to the meter bar. As a result of this scanning action, a 120 cps voltage is induced in the pickup coil. The phase of this voltage with respect to the voltage across the scanning motor terminals is a function of the relative positions of screw and bar.

The tape reader head employs a similar motor-driven screw to scan magnetic lines recorded in each of the four position tracks on the tape. If the lines are parallel to the sides of the tape, the 120-cps output voltage is in phase with the line voltage. When the lines are skewed to the left or right, however, the signal voltage undergoes a phase shift. The skewing of the lines is effected by the tape preparation equipment; the amount of skew is proportional to the feed rate desired, and the direction of skew indicates slide direction. A phase discriminator continuously compares the command and feedback voltages. If any phase difference exists, the servovalves are energized to move the slides in the proper direction. Because this is not an absolute system of measurement, the action of the hydraulic servos must be locked in closely with the tape commands. A safety circuit is provided to monitor the phase difference and open the servoloop if this difference exceeds a predetermined amount.

A feature of the control is a unique method of position display which employs a rotating drum graduated in 0.001-in. increments. This drum is illuminated by a stroboscopic light which is controlled by the phase shift of the measuring head. The drum rotates continuously at 3,600 rpm, and the light "stops" it at a position determined by the head output.

The Gisholt 1L turret lathe, complete with four-axis control and a special purpose analog computer for tape preparation, carries a price tag of about $120,000.

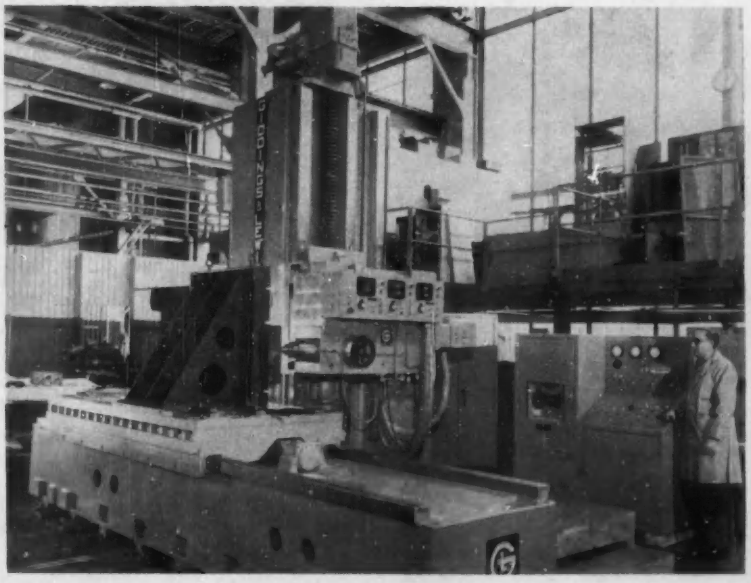
MILLING

GIDDINGS & LEWIS—GE

The efforts of the metalworking industry to extend numerical path control to die-making operations now appear ready to pay off. Actually, control systems capable of speeding die production have been available for some time. But machines and programming techniques were not. The major shortcoming of early tape-controlled machines was lack of sufficient rigidity for accurately milling hard materials at the speeds and feeds required for economic justification. And because die making has always been something of a "black art", it eluded reduction to the mathematical relationships called for by programmers.

G&L's Model B-20 DiMil, Figure 22, specifically designed for die sinking, is of extremely rigid mechanical design. In addition, it employs roller ways to provide minimum stick-slip characteristics for high response and double ballnut leadscrews in stiff, antibacklash servo drives. The working range of the Exposition model is 72 in. vertical travel, 84 in. table travel, and 18 in. spindle movement. The milling feed range of the machine is 0-60 in. per min, infinitely variable. The 32 spindle speeds cover 8½-1,800 rpm. GE's three-axis magnetic tape control system is employed for path control. Each axis is provided with digital readout which is completely separate from the tape control. This readout is provided by motor-driven odometer-like counters tied to the leadscrews by a synchro loop.

FIG. 22. Giddings & Lewis path-controlled machine designed for die sinking.



FAMCO—MINNEAPOLIS-HONEYWELL

One of the greatest testimonials to the economic advantages of tape control so far is the ratio of control cost to machine cost cited for the Famco 200 vertical milling machine. This is a small unit with a 3-hp spindle drive, a saddle mounted table capable of transverse and longitudinal motion, and a knee (which supports the table and saddle) capable of vertical movement. The cost of the manual machine is about $4,000; with tape control of X, Y and Z axes it is expected to sell for near $30,000.

The control is a sophisticated new point-to-point positioning system designed by Minneapolis-Honeywell. The input is 1-in., eight-channel paper tape handled in a mechanical reader. Tape data passes through a transistorized shift register into a buffer storage composed of banks of reed relays. The 30-in. table and the

9¾-in. saddle movements are powered by hydraulic motors through ballnut screws. A hydraulic cylinder moves the saddle through 6 in., with an additional 10 in. of manual saddle adjustment possible during initial setup by shifting the actuating cylinder through a leadscrew. Servovalves control the operation of the motors and the cylinder. The table rapidly traverses at 200 in. per min. Table and saddle feeds are continuously adjustable from ½ to 60 in. per min and the knee feed from 0.15 to 15 in. per min.

An especially unique feature of the Honeywell system is the design of the feedback transducers. Coarse positioning is accomplished by means of a metal scale consisting of a group of tracks in parallel. The tracks are actually cam surfaces having a binary coded arrangement of rises and falls. The scale for the 30-in. table movement has 10 cam tracks. As the table moves, precision limit switches sense the rises and falls and deliver output signals representing table position in binary code. Fine measurement beyond 0.1 in. is performed by a flat stainless steel scale mounted parallel to the axis of movement. The scale has a series of black lines 0.1 in. apart etched across its surface perpendicular to the axis. A light source and chopper carried by the moving member illuminates the scale. The amount of light falling on a photocell varies as the cell passes over the light and dark areas of the scale. This variation is analyzed to achieve an electrical resolution of 0.0001 in. The system for coarse measurement may be classified as digital and that for fine as analog.

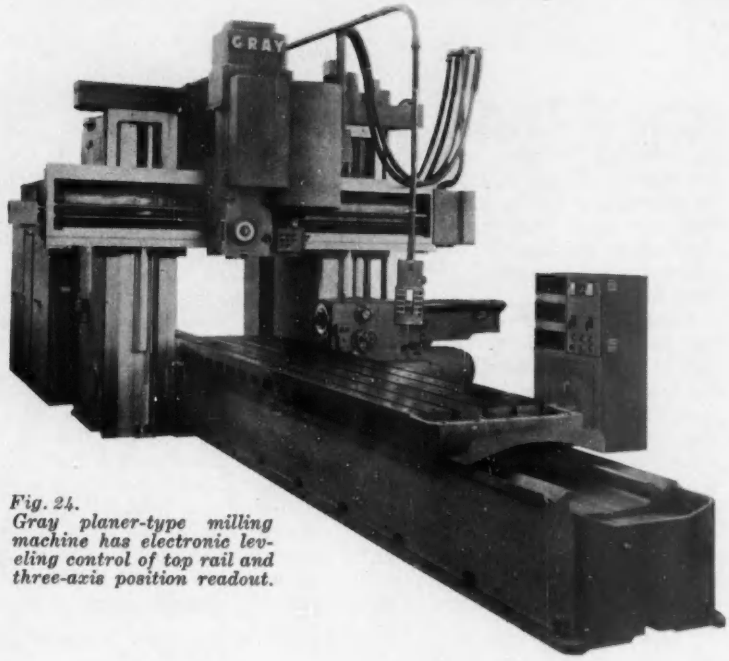


Fig. 24.
Gray planer-type milling machine has electronic leveling control of top rail and three-axis position readout.

BROWN & SHARPE-GE

A two-axis point-to-point positioning system is made to assume the task of path control in the Brown & Sharpe Numericam, Figure 23. This is a 5-hp vertical knee-type milling machine especially designed for cutting cam grooves into cylindrical and conical surfaces. The Numericam uses a GE Mark II positioning system for controlling longitudinal table movement, the rotation of a workholding fixture, and the downfeed of the cutter. The cams are actually produced by drilling many holes closely spaced along the cam path. Typical cams require about 700 individual points to make the milled path smooth enough.

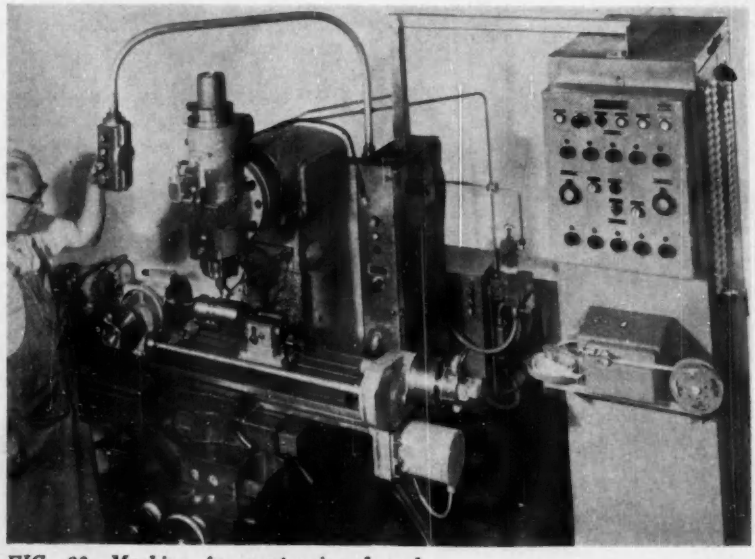


FIG. 23. Machine for contouring barrel cams uses only point-to-point control system.

The speed of machining with Numericam varies from about 10 points per min for a roughing cut to 16 points per min on light cuts. Each machined point is specified by five digits for each axis, to a one hundred thousandth part of a circle for the rotational axis, and to 0.0001 in. for the table travel. Brown & Sharpe has developed a program for the IBM 610 computer to prepare the tapes.

NEW ENGLAND MACHINE

The Magnetrace automatic profile milling machine manufactured by The New England Machine and Tool Co. features a full 360-deg tracer control. The machine is equipped with a 5-hp spindle drive motor to provide the high metal removal rate needed for tracing speeds as high as 80 in. per min. Stylus deflection of 0.0002 in. activates table and crosshead drives.

The tracing unit carries a spindle mounted on a ball pivot and free to swing in any direction. The lower end of this spindle holds a stylus the same diameter as the cutter being used. Any movement of the tracer spindle changes the gap length in two spark-gap sensing elements located at right angles to one another. The voltages across these gaps are proportional to the gap lengths and are output signals of the tracing unit. The command voltages are amplified and used to energize servo clutches.

GRAY-NORDEN

The G. A. Gray Co. teamed up with Norden Data Systems Div. for

the application of numerical control to the Gray planer-type milling machine, Figure 24. This machine features digital readout of rail head position on the crossrail, side head position on the housing, and table position on the bed. Measurement is by means of coded discs geared to the leadscrews or, where greater accuracy is needed, to separate precision racks. Full range zero offset is a feature. This same machine is equipped with an automatic leveling system for the cross rail which can be skewed under heavy loads. A plumbing potentiometer controls the operation of servomotors on the rail-leveling jacks.

Another new development is a Gray horizontal boring, drilling, and milling machine equipped with Norden's first completely digital positioning system. This makes use of coded discs for feedback in contrast to the linear synchros employed in earlier Norden controls. A tape punch as well as a tape reader can be supplied for record-playback operation.

PRATT & WHITNEY-BENDIX

P&W's Keller horizontal-spindle three dimensional contour milling machine, Figure 25, is the vehicle chosen by Bendix Corp. for introducing its brand new path control system*. Like the original system, the new control has built-in "directing" ability; that is, when it is given punched tape commands specifying the coordinates for the endpoints of a cut plus the desired feed rate, the system can generate continuous control signals to move the cutter from one end of the cut to the other. The new system, however, has capacity for circular interpolation in two axes as well as for linear interpolation in all three. Given endpoint coordinates, diameter, and feed rate it can move the cutter along circles and arcs of circles. The original control was equipped for linear interpolation only so that it was necessary for the programmer to divide arcs into series of straight lines before preparing the punched tape. The new control is expected to considerably reduce the need for using general purpose computers in parts programming.

Interpolation is performed by a transistorized computer based on digital differential analyzer techniques. These techniques lead to considerable economies in computer circuitry so that the new Bendix system is available at a lower cost than many systems that can interpolate linearly only. Input information is in binary coded decimal form, recorded on standard eight-channel magnetic tape. An added advantage of the circular interpolation feature is that it permits the use of a low cost mechanical tape reader. When linear interpolation only is available, the tape must contain much more information for an equivalent length of cut. Hence a high speed optical reader is required. The serial binary digital differential analyzer is equipped with magnetostrictive delay lines for storage.

In the original Bendix system the feedback transducers were pulse generators geared into the servo drives. The control was thus completely digital. The output of the interpolating computer was a stream of command pulses used to preset electronic registers with counts that could be compared directly with the data returned by the pulse generators. The positioning servos employed in the new control are of the phase-analog type, having synchro resolvers tied into the axes of motion. Now the pulse streams are converted to 200-cps signals that are phase shifted by an amount proportional to the counter settings. Phase detectors, error amplifiers, and hydraulic drives act to keep feedback and command voltages in phase.

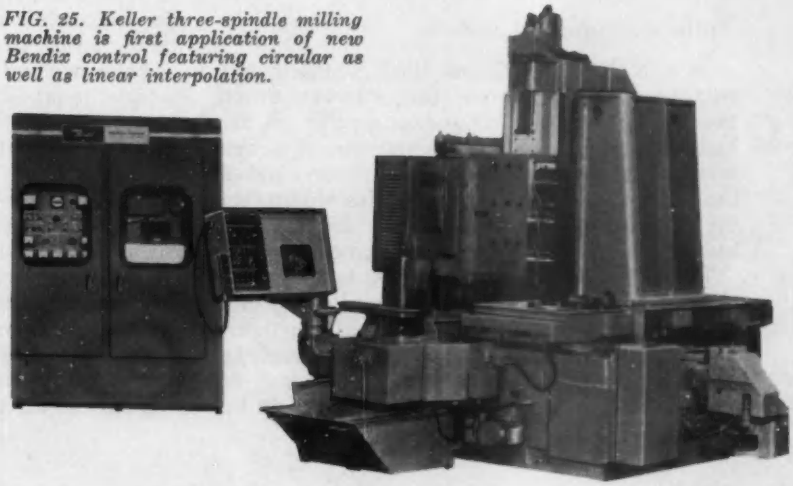
THOMPSON-DAGE

Numerical control has made possible another new type of machine: Thompson Grinder Co.'s Model TF5C Tape Forming Machine. In essence this is a planer-type grinder with the unique ability to grind contoured surfaces. The workpiece capacity of the grinder is 14 in. wide by 28 in. high by 60 in. long. The controlled motions are longitudinal table position, head elevation, and head crossfeed. All three motions are designed for tape control, but only two can be operated simultaneously by the two-axis control system. Hydraulic rams power the table and crossfeed, while a hydraulic motor is used for elevating the head. The 5-hp drive on the wheelhead is automatically adjusted as the wheel wears.

The numerical path control system is manufactured by Dage Div., Thompson Ramo Wooldridge, Inc. The input medium is 1-in. paper tape punched with data in binary coded decimal form. As the tape is read into the system by a Tally mechanical reader, the data is converted into straight decimal and placed in buffer storage. Decimal rather than binary numbering was chosen for the internal logic because it was felt to result in more easily assimilated maintenance procedures. The control system incorporates a built-in director capable of linear interpolation. The dimensional information on the tape is converted by the director into an equivalent number pulses for the X and Y motions. The rate of these pulses, which is proportional to feed rate on the machine, is controlled by adjusting the output of the clock oscillator. This is done normally in accordance with instructions on the tape. However, the machine operator can change feed rate at any time.

The director output phase-modulates the output of a 200-cps square-wave generator. Thus the command signals are translated into convenient analog form for controlling the operation of the hydraulic servos. The feedback transducers are resolvers geared to the wheelhead leadscrew and to precision racks along the X and Y axes.

FIG. 25. Keller three-spindle milling machine is first application of new Bendix control featuring circular as well as linear interpolation.



* A detailed description of the Bendix system will be published in a future issue of CONTROL ENGINEERING.

Electronic Controls Replace Pneumatics on Gas Compressors

Below the level of the large scale, completely automatic processing or manufacturing system, there is a multitude of smaller scope automatic unit operations. These are characterized by the fact that they perform only a specific portion of the total production function and can often be looked at as complete systems. The automatic operations discussed in this section do not share a specific function, but rather were picked for their uniqueness to show the possibility of controlling all sorts of equipment. They include the electronic control of gas compressors, a machine for punched tape control of carpet patterns, an automatic weighing and compensating system, and a survey of European blending systems and their application.

VINCENT A. RIGGIO
U. S. Industrial Chemicals Co.

Because of the many and varied applications of electronic process controls, it would be difficult to single out any one system and call it "typical". Each has its own specific requirements and is designed to handle a particular problem in a particular way. The purpose of the following system descriptions then is not to cite typical applications, but simply to indicate the versatility of electronic controls in one small area, compressor control, and to point out some of the reasons why electronics was chosen.

Turbine-compressor system

At U.S. Industrial Chemical Co.'s newest polyethylene plant in Houston, Tex., a turbine driven, two-stage reciprocating compressor supplies gas to a high pressure manifold. Ideally, pressure of this gas must be held constant regardless of variations in the consumption rate. To effect this requirement the company's instrument engineers developed the cascade control system shown in Figure 1.

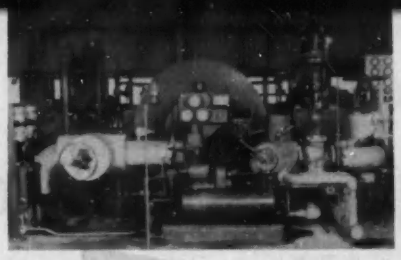
This system actually consists of two complete electronic control loops interconnected by an override adapter. Under normal conditions the system maintains gas pressure by varying turbine speed, i.e. increases speed as pressure tries to drop and decreases speed as pressure tries to increase. At the same time the valve in the recirculating line around the compressor is closed to avoid any waste of power. In its normal mode of operation, then, the system provides simple cascade control with the output of the pressure controller adjusting the setpoint of the speed controller.

Occasionally, however, the tendency towards a pressure buildup in the manifold continues to the point where further throttling of steam to the turbine becomes impractical because of the turbine's own critical speed. At this point the override adapter and the recirculating valve come into play. As shown in the schematic, both these elements receive the 1 to 5-ma dc output of the pressure recorder-controller, but each is sensitive to only half of this range. With normal gas consumption, output of the PRC is between 3 and 5 ma dc. This enables the override adapter to provide the speed recorder-controller with a setpoint adjustment covering the entire allowable speed range of the turbine. With outputs below 3 ma dc, however, the override adapter becomes insensitive to further variations and provides a constant output. Essentially this fixes the turbine speed at some constant minimum value.

The recirculating valve operates at the other end of the PRC's output range. It is completely closed for outputs between 5 and 3 ma, begins to open at 3 ma, and is fully opened at 1 ma. Thus the system maintains pressure in either of two ways, depending on whether gas consumption is high or low.

Motor-compressor system

Another electronic control system recently installed at this same plant involves a similar process. In this case however, a large ac motor rather than a turbine supplies the motive power, and compressor speed rather than gas pressure is the controlled variable. Elements of the system are shown schematically in Figure 2. A powerful eddy-current clutch couples the motor to the four-cylinder gas compressor. As in the system described above, a dc tachometer generator senses compressor speed and, via a standard dc-to-ac converter, feeds a proportional signal to the locally mounted speed recorder-controller as well as to a remote recorder in the control room. Controller output is then amplified and applied to a thyratron control unit which supplies the necessary direct current to the clutch.



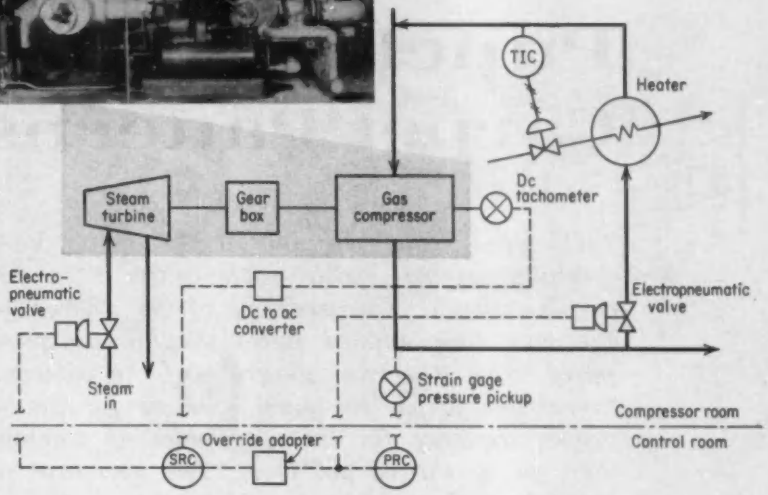


FIG. 1. Electronic control system for a turbine-driven compressor in a polyethylene plant.

Main feature of this system is its two-speed motorized setpoint unit which permits either fast or slow setpoint adjustments. These adjustments can be made either in the compressor room or at the main control panel. There is, however, one difference. Adjustment can always be made at the compressor room board, but not always at the main panels.

Electronics vs pneumatics

Of the two systems described above, only the first actually has a pneumatic counterpart. A number of similar turbine-compressor systems, all pneumatically controlled, perform the same function at the company's Tuscola, Ill., plant. Detailed information on the performance and maintenance of these systems, over a period of more than five years, is readily available to the company's instrument engineers and will enable them to make a direct comparison with the performance and maintenance of the Houston systems.

What little information is available so far indicates that maintenance and field calibration of the electronic system are simpler. As far as performance is concerned, the electronic system again has a slight edge in that signal lag is no longer a problem. Another factor contributing to the improved response of the new system is its ability to use three-mode controllers. The dynamics of the pneumatic system preclude the use of rate action; hence, only the proportional-reset modes are used.

No such comparison can be made in evaluating the performance of the motor-driven compressor system, nor is any really necessary. Clearly this is an example of a process to which the application of pneumatic controls would be hard to justify. The controlled variable, speed, is readily sensed and corrected by means of electrical equipment, i.e., the tachometer generator and the eddy-current clutch. Any attempt to insert pneumatic instruments between these two points would not only involve additional conversion equipment but would also adversely affect the over-all response of the system.

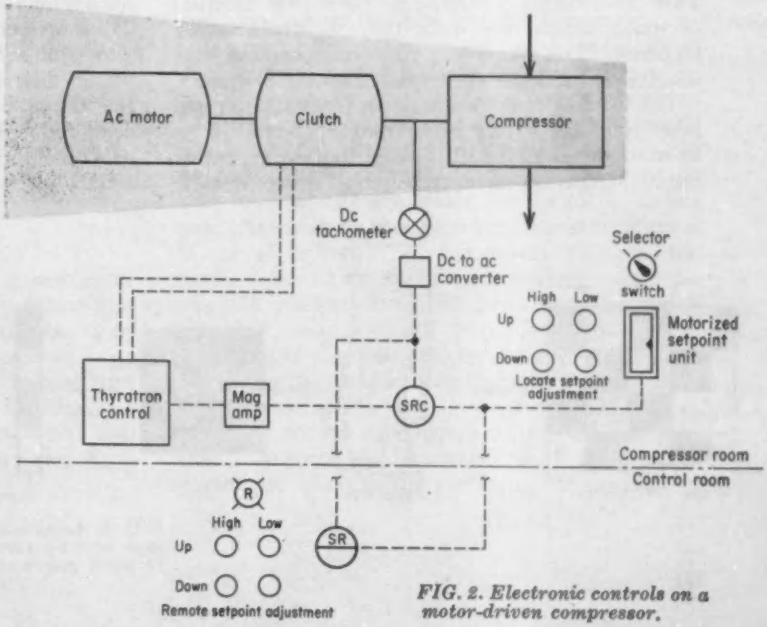


FIG. 2. Electronic controls on a motor-driven compressor.

Punched Tape Controls Carpet Patterns

THE GIST: The weaving of Axminster carpets requires many specially wound spools with colors arranged according to the carpet pattern. The positions of the colored yarns in these spools are now programmed automatically by a punched paper tape prepared from a master diagram of the pattern. The tape triggers thyratrons which set yarn carriers for the selected colors in the proper sequence for the spool winding machine. The many spools then go to the carpet loom. The new tape programmed machine has cut spool winding time by 50 to 80 percent and can be operated by unskilled help.

W. H. T. NEALL
The Birstall Carpet Co., Yorkshire, England

Axminster carpets are woven a row at a time, with seven threads or yarns per inch across the width of the carpet. The finished carpet usually has seven rows per inch lengthwise. Each individual yarn in a row can be a different color from its neighbors, and as many as 36 colors can be used in a single row. The yarns are supplied to the loom from long spools wound with threads of the correct color in each yarn position according to the pattern. Since the colors can also change from row to row in any yarn position, it is necessary to change the spool from which the carpet is loomed if the pattern requires that the color change in even one yarn position. Thus an intricate pattern can use a large number of spools which may differ only slightly in color sequence. The spools are conveyed overhead and inserted in the loom as demanded by the pattern.

The winding of the many spools for the Axminster loom has been a time consuming operation (6 to 16 min per spool) which limited the less expensive carpet designs to moderately simple patterns with small color ranges. It took four to six months to develop skilled operators for the spool winding machines. An automatic setting machine for the spool winder was designed originally by the Magee Carpet Co. of Bloomsburg, Pa. An electronic version of this machine called the Homfray machine has been developed that uses a special punched paper tape to position the yarn on the spool. The Homfray machine at Birstall positions 1,000 yarns per min, reduces spool setup time to 3 min, and eliminates the operator training period. Here's how it works:

The selection system restricts the designer to 50 colors of which 36 may appear in any single row of the pattern. The whole cycle of the recurring pattern is first shown row by row on a full scale colored master diagram, Figure 1. Each row is broken down into the number of yarns (or color shots) to be wound on the spool. A 36-in. wide carpet will have 252 shots per row.

A 6-in. wide punched tape is prepared from the master diagram to control selection of the yarns on the setting machine. The tape carries the complete color coding for each row. Across the width of the paper are 37 tracks in which holes may be punched, a track for each color and the 37th track for single

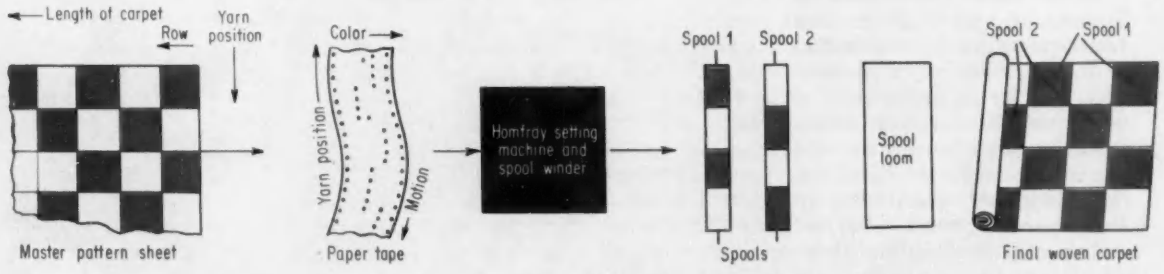


FIG. 1. Axminster carpet pattern is translated to punched tape row by row. Punched tape then controls position of yarn colors on spools from which carpet is loomed.

FIG. 3. Unused yarn ends are tied to yarn store. Spool winder is in foreground, setting machine in rear.

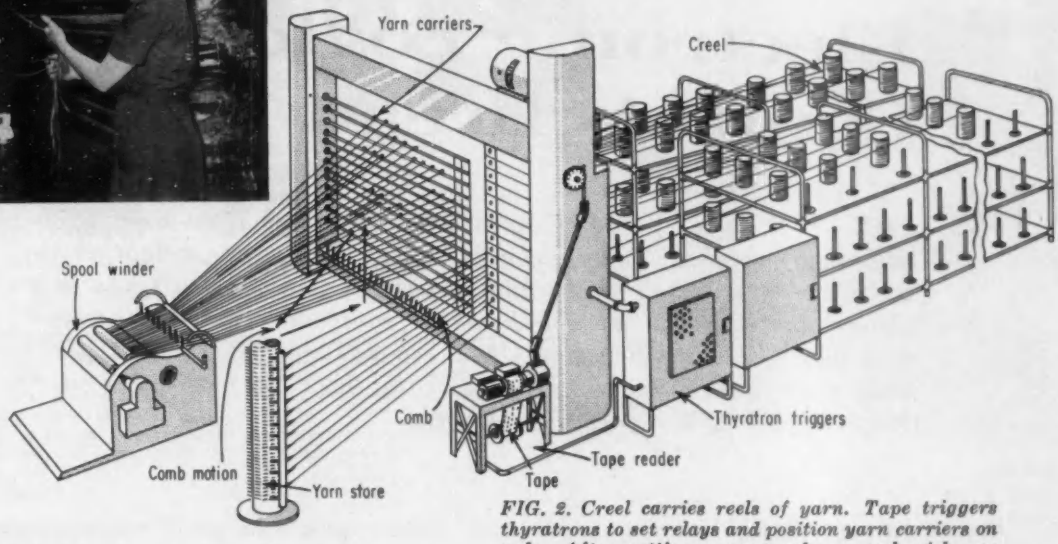


FIG. 2. Creel carries reels of yarn. Tape triggers thyratrons to set relays and position yarn carriers on rods. After setting correct colors, comb picks up yarn ends and delivers them in sequence to winder.

punchings which separate the pattern rows. Each pitch of the paper represents a yarn position in the row which is arranged lengthwise along the tape. A group of 10 yarns of one color will therefore appear as 10 punchings in one track. This logical arrangement is permissible because the paper is read simultaneously with the selection of the yarn color and desirable because it enables alterations either for correction or change of design to be made easily without highly skilled operators. And an elementary transparent cursor can be moved along the paper tape to read the pattern quickly and easily.

An automatic cursor in a special tape preparation machine scans the pattern sheet row by row. At each point in the row the operator depresses numbered keys corresponding to the color required. A control key marks the finish of each row on tape.

The next step after tape preparation is running the tape through a quantity analyzer where two sets of 50 counters alternately record the total number of each of the color shots in the rows. The total yarn demand is calculated from these counts for each color. This automatic determination of yarn quantities effects an additional economic saving since previously quantities were only roughly estimated.

Preparing the spools

When the tape has been prepared, it is inserted into the reading head on the Homfray setting machine, Figure 2, which uses a kind of abacus of pulley-like yarn carriers between the creel—a large frame carrying a battery of differently colored yarn reels—and the actual spool winding machine. A bridge structure carries 36 pairs of horizontal rods along which individual yarn carriers can slide. Each rod has 126 yarn carriers.

The main timing system and mechanical drive for the machine is a common cam shaft driven from a 7½-hp motor. The first operation cancels the previous setting by causing a collector block to push all carriers against stops at the right hand side of the gantry. Bevel gears then operate a locking arrangement which enables all the carriers to be drawn back towards the left hand side. Simultaneously a dog clutch engages to advance the punched tape. At each position brushes sense the tape coding and select the rod for the required yarn color. A thyratron trigger circuit operates a relay to place a restraint on the free end of a lever so that the lever will follow the camshaft profile. Movement of the lever rotates a spider rod running through all the carriers on the selected rod and releases the last carrier in the group to drop it off at the yarn position corresponding to the tape position. Interlock circuits prevent more than one relay operating simultaneously, and a quench circuit then resets the thyratrons and advances the tape to the next yarn position.

With all yarn carriers in position, the next operation inserts the selected yarns in the spool winding machine. A light collapsible comb is raised vertically from the base of the machine parallel to the carrier rods. As the comb rises, each yarn thread is collected in one of its teeth. At the top of its travel, the comb slides down under gravity along telescopic supports to the spool winding machine, simultaneously changing length to suit the winding pitch. The ends of the yarn selected by the machine are inserted in the spool winder, and the discarded yarns are removed and tied to a warp clamp, Figure 3. After the correct selection of yarn colors and positions, the spool winder rotates to fill the required number of spools to the predetermined amount.

Electronic Logic Controls Bread Weight

THE GIST: Bread produced by commercial bakers must meet minimum legal weights. The problem is to keep the average weight above minimum by as small an amount as possible without producing any underweight loaves. The bread weight controller described weighs each loaf and adds increments to bring loaf weight just over minimum from a slightly low average maintained by feedback to the dough divider which forms the loaves.

WILLIAM J. FOWLER
Food Machinery and Chemical Corp.

Bakers must control the weight of bread loaves for both legal and economic reasons. Most states have laws which require that a finished loaf of bread or the average of several loaves weigh within a certain range. A tolerance of one ounce per pound is typical. Bakers normally produce bread loaf weights somewhat higher than the allowable minimums. The value of extra bread given away by wholesale bakeries in this country is estimated at $17 million per year. A typical wholesale bakery may lose about $17,000 per year, much of which can now be saved by an improved weight control method.

Bread dough is mixed and given time to rise before it is used. Schedules are arranged so that one container of dough follows another in the proper order. Pieces of dough are then sized volumetrically into loaves six or eight at a time in pockets in a dough divider and dropped on a conveyor. The dough pieces are then rounded, put in a pan, "proofed", baked, cooled, sliced, and wrapped. Three hours may elapse between sizing of pieces by the divider and wrapping of the completed bread loaf. The weight changes during this time because of "bake-out" and slicing losses, but the change is amazingly predictable. Modern temperature control during baking and cooling makes it possible to allow for this loss as the piece is being sized at the divider.

The weight control problem thus exists at the divider; if a piece of dough of a certain weight can be produced there, then a loaf of bread will result whose weight is an almost constant amount less than the dough piece weight. Normal manual weight control methods call for the divider operator to spot-check individual pieces of dough as they come from the divider and then adjust the divider as the weight seems to indicate. Before operation, volume of individual pockets can be adjusted with a wrench; during operation an over-all volume adjustment may be made with a hand crank. Large pocket-to-pocket weight variations occur even for very carefully adjusted dividers because the specific gravity of the dough continuously changes as it grows older, because new dough is added before all the old dough has been used, and because gas bubbles form in the dough. These variations are random and cannot be controlled by the operator. The operator's primary function is to adjust the divider to produce the desired average weight by correcting for the variation due to constant expansion of the dough. To be sure that few underweight dough pieces are made, the average weight must be greater than if no pocket-to-pocket weight variation existed.

Control of the pocket-to-pocket weight variations presently seems impractical. The problem has been solved by weighing each dough piece as it comes from the divider and adjusting its weight by adding small amounts of dough. A feedback signal controls the divider so that the average dough piece weight is somewhat less than the desired final dough piece weight. The weight control machine can add either of two increment sizes or both of them. Pieces so underweight that insufficient dough can be added and overweight pieces are rejected to be resized.

Figures 1 and 2 show the weight control machine and its electronic control system. Dough pieces from the divider are carried on a flexible conveyor belt across a deflecting scale, then to a cross conveyor belt which takes the pieces in one direction if they are to be rejected and in the other direction to be finished. Necessary increments of dough are added by two flippers as the dough piece gets to the cross conveyor belt. The flippers actually throw the dough increments at the dough pieces. The increments stick to the dough pieces and are so pressed and mixed into them in the subsequent rounder and moulder that they cannot be detected in the final bread loaf. The machine will handle 3-lb dough pieces at rates up to 160 pieces per min.

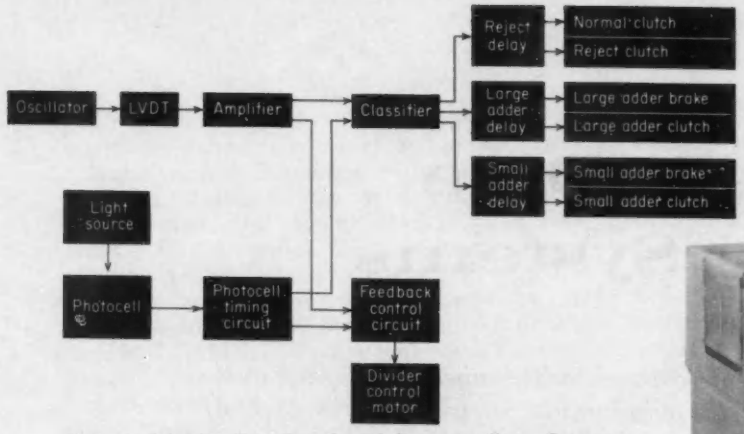


FIG. 1 (right). The bread weight controller. Conveyor moves to right. Dough piece at left has not yet been weighed; piece in center has been weighed and is about to receive increment of dough from flipper arm just below dough hopper; piece at right has been acted upon and is being moved off by cross conveyor belt. The weighing scale and photocells are just to right of the left piece of dough.

FIG. 2. Thyratron triggered relay logic operates magnetic clutches and brakes in bread weight controller.

The bread is weighed on the move by a preloaded leaf spring scale which does not deflect unless the weight exceeds a certain value. A linear variable differential transformer (LVDT) is used as a transducer to detect scale deflection. The LVDT primary winding is excited by an oscillator designed for good amplitude stability and pure sinusoidal wave form. The output voltage of the LVDT is proportional to the amount by which the weight of the dough piece exceeds the preload. The LVDT output signal is amplified to the power level necessary for the classifier and feedback control circuits. The amplifier also has an output that will drive a standard oscillograph.

The timing of the classifier and feedback control actions is measured from the moment the dough piece breaks a photocell beam just before maximum scale deflection is reached. This photocell signal clears the classifier of previous information to accept a new amplified output signal and also returns the feedback control peak detection circuit to a selected reference so that the new peak amplifier voltage may be correctly examined. The photocell circuit "times out" after a predetermined time.

The classifier consists of five bistable circuits based on thyratrons with progressively higher triggering points and acts upon the peak amplifier output. An amplifier output too small to trigger any of the bistable circuits produces an underweight-reject decision, one which triggers only one of them produces an add-both-increments decision, and so on. These circuits retain the decision made and, with other logic circuitry using neon glow tubes, start the action of following circuits.

Due to the time delay in transporting the dough piece from the scale to the point at which it is rejected or incremented, the decision made by the classifier must not be acted upon immediately. If a pass decision has been made, no further action is required. But for other decisions delay circuits hold the classifier decision so that each dough piece is acted upon as it reaches the proper position. The delay circuits are termed reject delay, large increment delay, and small increment delay.

Pieces of dough classified as underweight or overweight are both rejected in the same way by the cross conveyor belt, so only one reject delay circuit is needed. A fixed time after a reject signal from the classifier, the reject delay circuit causes the cross conveyor belt to reverse its running direction long enough for the chosen dough piece to be rejected. If the next piece of dough is not to be rejected, the belt returns to its normal direction in time to convey the piece to the rounder; but if the next piece is also to be rejected, the belt continues to run in the reverse direction until the piece has been rejected. This procedure prevents wear due to unnecessary changes of belt direction.

By the time a given piece of dough has been rejected, the classifier may have already made decisions on two more pieces. Thus the reject delay circuit must be able to store and delay two signals at once, and this is done by cascaded monostable multivibrators. A thyratron actuated relay energizes the reject or the normal clutch to control the belt.

In lenghty tests in a bakery production line, comparisons to an unusually well-controlled manually adjusted divider showed definite advantages in automatic control. For 1½-lb white bread, dough savings ranged from 0.25 to 0.40 oz per loaf compared to the same divider under manual control. The frequency distribution of weights for finished bread obtained with the bread weight controller typically has a standard deviation and coefficient of variation 38 percent less than that produced with careful manual divider control and 47 percent less than that obtained with normal divider control. This allows a substantial reduction of average dough weight. In the bakery where these tests were run, 0.3 oz of dough saved for each 1½-lb loaf of white bread alone would save about $9,500 per year.

J. A. Abbott, T. E. Roberts, Jr., and P. R. Bunnelle contributed to the design of the bread weight controller.

Four Up-To-Date Blending Systems

THE GIST: One of the chief economic advantages of efficient automatic blending systems is the elimination, in whole or in part, of expensive storage capacity. But controlling the blend of two or more component streams—simple as it may appear to the uninitiated—can pose some difficult design problems. On the following pages, the author reviews some of these problems and shows how they have been handled in four modern systems. Examples cited cover both the ratio-flow and fixed-flow variable-orifice techniques.

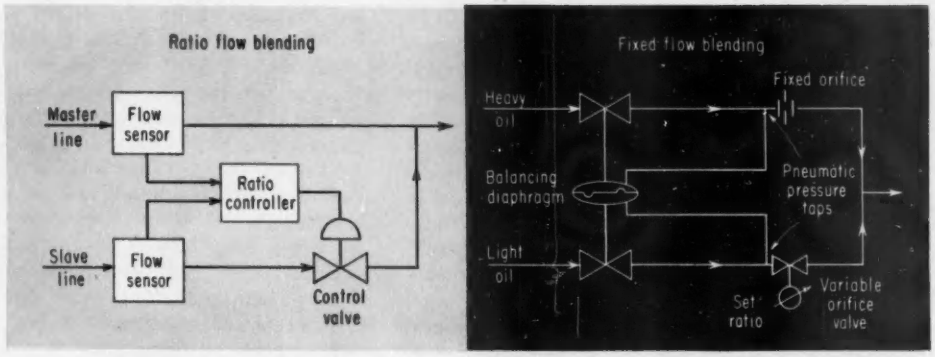


FIG. 1. The two basic blending techniques: left, ratio flow; right, fixed flow variable orifice.

DEREK BARLOW
Control Engineering, London

Blending control in its simplest form is the mixing together of two or more liquids in a predetermined ratio. Simple as it sounds, there are hidden snags when it comes to practice. Questions immediately arise regarding the blending basis (volume or mass), accuracy required, effects of flow and temperature changes, and the economics involved.

Chief specification setter for blending systems is the petrochemical industry where, for one thing, a good blending system can eliminate storage tank farms and a final product can be blended right at the producing units and pumped straight into tankers or railcars without intermediate storage.

At British Petroleum's Dinslaken refinery, for example, mechanical blending controls have eliminated all intermediate tankage between the producing units and the terminal area. Only storage left in the system is at small delay tanks where errors in the mechanically produced blend can be corrected before shipping. The seven to eight components in the final blend are metered from the producing units on positive displacement meters with their shaft speeds geared down in the desired ratio. Differential gearing compares the meter speeds, and any variation adjusts the setpoint of a controller to correct the flow rates. With accuracy of the mechanical blending system limited to within 1 percent, the blended product can still be off-spec during the run, requiring periodic laboratory sampling and on-stream adjustment. The end-of-the-line storage tanks provide integration of the additional extra component amounts added.

Another reason for blending systems is that petroleum products are seldom marketed as pure fractions of components *A*, *B*, and *C*. Instead they consist of a number of components blended to meet a com-

posite specification made up from individual specifications for viscosity, flash point, and so on.

Higher accuracy blending systems (blends correct to within 0.1 percent) pay for their increased cost by producing a final product closer to specification limits. This eliminates, for example, the present give-away of costly cutter oils which are added to fuel oil to get the correct blend viscosity. A case in point—although not down to the 0.1 percent error level—is Mobil Oil's new terminal in Cheshire, England. Here a boost in blending accuracies on fuel oil stocks from 95 percent up to 99 percent is saving Mobil 3 to 4 percent on every ton blended, and this with an initial equipment cost of only $5,400 for a two-component system.

Flow rate variations also complicate the blending problem. Blending by digital techniques is simple if the exact number of gallons to be run through the blender is known. This final gallon throughput can then be set into the equipment digitally, and simple dividing circuits will control the amount of each component. But in filling tankers and railcars, blending by ratioing the final required quantity would be impossible. Ideally blending must be a continuous feed-forward operation and not based on the predetermined final throughput.

Temperature and viscosity also require compensation. Every degree deviation from a mean temperature of 60 deg F, if not compensated, means a 47-ton error in a 10,000-ton throughput. A 1-deg C variation can cause a 10-percent viscosity change. Although built-in temperature compensating devices help, the demand for increased blend accuracy further complicates the problem.

Equipment types

Ratio flow blending and fixed flow variable orifice systems are the two main blending techniques. Figure 1 shows the basics of each approach.

Ratio flow systems can be pneumatic, mechanical, or electronic, while the variable orifice is basically pneumatic in operation. By adding viscosity control to a variable orifice system, its error can be held to about 1 percent. Mechanical or electronic ratio, on the other hand, can reduce error to as little as 0.1 percent, but is more expensive.

FOUR CURRENT APPLICATIONS

FIXED FLOW VARIABLE ORIFICE—
Fisher Governor Co. Ltd., Rochester, England

Example of the fixed flow variable orifice is the Fisher Type 431 blending unit. As in Figure 1 (right side) the two oils to be blended are pumped through pressure equalizing valves to maintain equal pressures upstream of the orifices. These valves have a common spindle to which is attached a balancing diaphragm. Movement of the diaphragm differentially adjusts the upstream pressures. Equal pressure at the main and subsidiary line orifices ensures that the ratio of flow through each is proportional to their respective areas.

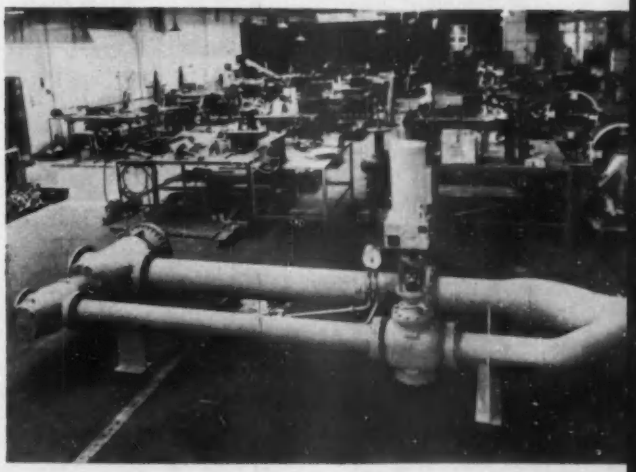
On the main line the orifice size is fixed and is predetermined from the flow rate requirements. Viscosity/temperature variations are eliminated by using on the main line heavy oil flows a specially modified Witte orifice which gives a constant orifice discharge coefficient all the way down to a Reynolds number of 50.

With constant output from the main line orifice, blend ratio is adjusted by means of the variable orifice. This is a single-ported globe valve fitted with a parabolic plug-type inner valve. Flow ratios are calculated from a three-digit mechanical counter indicating the valve piston position; slots machined in the piston wall give good near-shut characteristics.

Suitable only for two component blending, the system offers a blend range of from 20 to 1 down to 1 to 1 with a 95 percent accuracy. Outstanding advantage of the system is its complete independence of external pneumatic or electric supplies.

In the Mobil Oil installation four similar units (with 10-inch and 6-inch heavy and light oil component arms and a 12-inch outlet) hold the final mix viscosity to within 2 percent. Their design, however, requires the addition of an on-off vernier control drive. Dual rotating cup viscometers, insensitive to temperature changes, measure viscosity of the blend and position switches which actuate the vernier control drives. Figure 2 shows one such unit assembled at Fisher Governor Co.'s works in Rochester, England.

FIG. 2. Fisher fixed flow variable orifice blender with an electric motor drive on the variable orifice valve to permit viscosity correction.



ROTOL IN-LINE BLENDING SYSTEMS—
Rotol Ltd., Gloucester, England

A digital system proposed by Rotol Ltd. maintains correct flow proportions even under varying flow rate conditions. In this system one line produces a master signal proportional to its component flow, and each other line is automatically controlled by following the master signal.

Figure 3 shows the basic system applied to a two-component blend. Positive displacement meters in each line drive photoelectric pulse generators, whose outputs feed preset counters. Whenever the preset number of counts is reached, the counter emits a pulse. When the output rates of the master and slave counters are equal and in phase, the blending proportions are correct. Variations in total flow and flow rate are detected in separate error circuits and the combined error signal controls the valve in the slave flowline. An integrating circuit maintains valve position during zero error signals.

Each line in the system requires a positive displacement meter, pulse generator, and a counter unit. Four decade dials on the cold cathode counters set the number of input pulses required before an output pulse is emitted. The nth pulse resets the counter and simultaneously feeds the counter output pulse to the control unit. A subsidiary circuit also produces a half period pulse for every n/2 input pulses, which is also fed into the control unit.

The two error circuits compare the master and slave incoming pulses. The flow rate circuit, particularly useful during startup and shutdown, detects the pulse rate differences and equalizes the flows, while the total flow circuit detects phase errors between master and slave signals.

In the total flow error circuit, which exercises the most control, incoming pulses trigger a master and a slave flip-flop operating with a 90-deg phase difference between outputs. One output of the master flip-flop (in its "on" position) opens a diode gate operating on the slave flip-flop output. The 90-deg initial phase difference allows for bidirectional corrections. The diode gate output is smoothed and operates the valve positioning motor.

Flow variations on either master or slave lines are corrected in the flow rate error circuit by adjusting the slave valve to maintain that component's flow in its correct proportion. The master and slave n-pulse outputs each trigger a monostable flip-flop whose square wave outputs are summed in a smoothing circuit. This summed dc output from both master and slave trigger circuits is added to total flow error voltage to provide an overriding valve positioning signal.

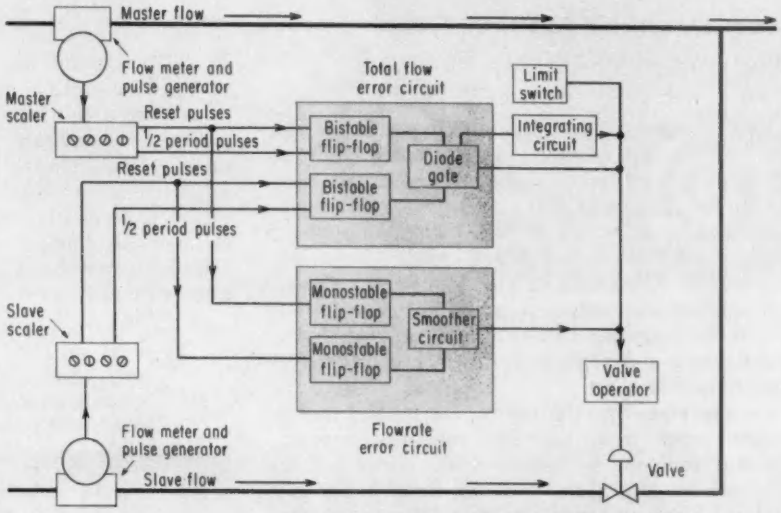


FIG. 3. Basic schematic of Rotol blending system.

THE CJB DIGITAL BLENDER—
Constructors John Brown Ltd., London

Features of the CJB digital blender—still undergoing final test trials (Figure 4)—are its absolute accuracy and ability to maintain accuracy regardless of over-all flow rates. Using transistorized digital techniques, the system is particularly suited for tanker loading installations and other applications where frequent flow rate changes occur.

The system (Figure 5) consist of a master unit and one component unit for each controlled component. The master unit contains the system power supplies and a common pulse generator. Each component unit contains a dividing circuit and a differential counter plus other control circuits.

From the common generator, pulses are fed to each of the dividers. A knob on the master unit panel controls the generator pulse recurrence rate over a range of 10,000-100,000 pulses per sec, adjusting it to the required flow rate.

The dividing units (modified counters) count up to a preset number then emit an output pulse. At the same time the differential counters reset themselves to zero. The number of output pulses from

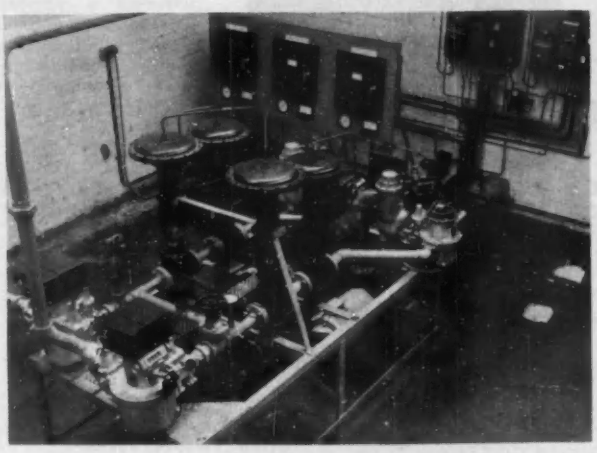


FIG. 4. Test rig for CJB digital blender.

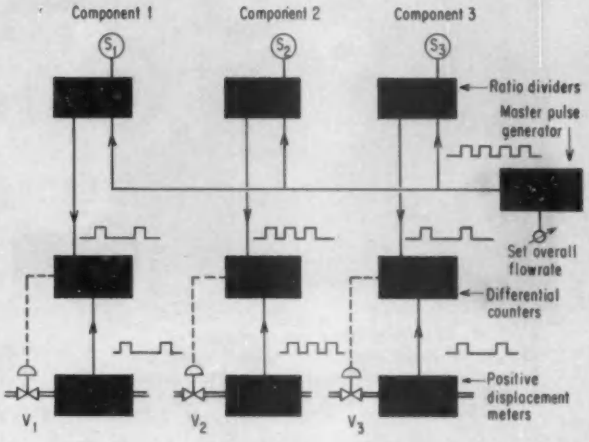


FIG. 5. Master pulse generator controls over-all flow rates in all lines on CJB digital system.

the counters is in a strictly controlled ratio to the number of incoming pulses. Four decade switches set this ratio to four decimal figures within the range 999-9,999.

Output pulses from the dividers are fed to one side of the differential counters which have a 2,048-count capacity. The counter zero point is set at 1,024 counts, and pulses arriving from the dividing circuits increase this count. The other counter input is that of the actual flow signalled from the displacement meters; this reduces the count. With equality of the two pulse rates, the count in the counter remains constant. Any difference in these two input pulse rates will accumulate counts in the differential counter either above or below the 1,024 midpoint. A digital-analog converter transforms this output count into a 1 to 5-ma control signal, 3-ma corresponding to the 1,024 count. Simple conversion techniques are used, as the analog signal has no effect on blend accuracy; it merely positions the flow control valve in the appropriate component line.

The overriding flow rate control exercised by varying the master generator pulse rate adjusts the over-all rate at which individual component pulses are fed to the differential counters. If they exceed those of the incoming meter pulses, a count accumulates in all differential counters, and all flow control valves open proportionally to increase flow and cancel this difference. This single knob flow rate control ensures blending accuracy to within 1 part in a 1,000.

On each component unit a separate pulse dividing circuit fed from the displacement meter pulses operates an electromechanical indicator totalizing the component quantity used. Adjustment of the circuit dividing ratio on three decade dials provides direct output readings in gallons, liters, or any other unit measure.

Blending operations, after setup of the various dividing ratios, are controlled by a three-position switch on the master unit. On "Standby" all pumps are running, but flow lines are stopped by pneumatic shutoff valves. The master generator pulses are disconnected from the differential counters which reset to the 1,024 position, while a reset button sets the flow totalizers to zero. Switching over to "Blend" opens the shutoff valve, and master generator pulses start entering the differential counters where the accumulating counts open the control valves.

As liquid flow starts, pulses from the positive displacement meters reduce the count in the differential counters towards its midvalue. A meter on each component unit panel indicates the analog control signal being transmitted by the unit. When blending of the component is correct, this reads 3 ma.

A blend is terminated by switching back to the standby position. This can be either done manually when a predetermined quantity has flowed through the system or automatically by a pulse from a preset integrating flowmeter. Then the shutoff valves in each line close, the differential counters are zeroed, and the pumps remain running. Total amounts of each component fed into the blend remain on the electromechanical counters.

Third position of the master switch, "Blowback", allows the pipes to be cleaned back to the storage tanks by blowing through with air or inert gas. A float operated switch and warning light on the component panel indicate when blowback is complete. The same system, when blending is in operation, warns of lines running empty due to exhaustion of the particular component and automatically reverts the blender to the standby condition. Other warning systems guard against losing control of one of the flows, overpressure in the manifold, and overheating of any component. These operate when the counts in the differential counters accumulate to one or another of the limits set at 992 counts above or below the midvalue.

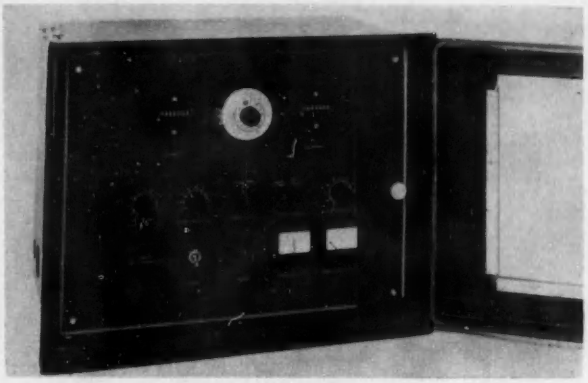


FIG. 6. Single cabinet construction of the Shell ratio controller houses ratio bridge, final proportional-plus-reset controller, and actual ratio setting controls.

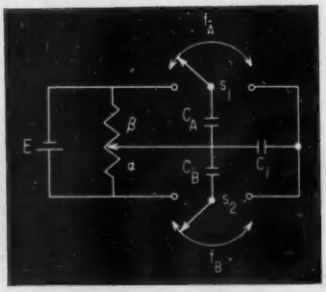


FIG. 8. Capacitor C_t performs a memory function in the Shell ratio bridge, any charge accumulating on it showing that $\beta C_A f_A \propto C_B f_B$

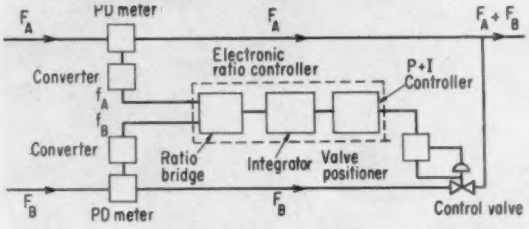


FIG. 7. Schematic of the Shell blending system.

ELECTRONIC RATIO FLOW SYSTEM—

Koninklijke/Shell Laboratorium, Amsterdam, Netherlands

In service at the Shell refineries for bitumen cutback blending, an electronic ratio flow controller (Figure 6) eliminates the infinitely variable mechanical gear box and the close positioning of the positive displacement meters required in the equivalent mechanical ratio flow system. Feature of the system is regulation not only of instantaneous flow ratios but also control of the component ratio over the total integrated blend. A simple potentiometric control sets the blending ratios of components to any value between 1 to 10 and 10 to 1. Accuracy of blend is dependent solely on the flow measuring system used as input to the ratio controller. Using positive displacement meters, blending accuracies of within 0.1 percent are possible over a 10 to 1 flow rate range.

Figure 7 shows the system schematic. Connected to the output shaft of each positive displacement meter are electrical commutators operating under intrinsically safe conditions. These feed pulse signals into a ratio bridge with a pulse rate proportional to the displacement meter's shaft speed and hence to flow rate of each component.

When the flow rates are within their desired ratio, the ratio bridge provides zero output. With disturbances present, a bridge output appears, is integrated, and operates a proportional-plus-reset controller. Correct flow rate in the slave line is restored by operation of the flow control valve from the controller via an electropneumatic valve positioner.

Operation of the ratio bridge is shown in Figure 8 where the switches S_1 and S_2 are operated from the positive displacement meter shaft commutators. Left-hand switch positions charge the capacitors C_A and C_B, the right-hand positions discharging them both into the memory capacity C_t. Action of the ratio bridge and its integrator is analogous to a bucket and bathtub operation where, armed with equal size buckets, one man attempts to fill the bath and the other to empty it. The tub level only remains constant if both men work at the same speed. In the electronic system the final controller maintains constant flow ratio by increasing or decreasing the speed of one of the switches.

If the ratio bridge capacitors C_A and C_B are equal and the ratio potentiometer set in its mid position $\alpha = \beta$, C_A and C_B charge to the same potential, and their algebriac sum when switched to the memory capacitor C_t is zero. Capacitor C_t remains uncharged provided the two switching rates are equal.

At any position of the potentiometer, if the charge on the memory capacitor is to remain zero, the switching frequencies f_A and f_B must satisfy the relation $\alpha f_A = \beta f_B$. Variation of either switching speed accumulates a charge E on the capacitor which is used to correct the appropriate flow rate. Blending ratios are simply set by varying the potentiometer ratio.

Disturbances in the blend last only for the period that an error charge exists on the memory capacitor. The total integrated blend is correct as soon as the charge returns to zero, the entire system acting as a controller with reset action. The accumulated charge on the memory capacitor measures, during the disturbance period, the fluid quantity in excess or missing from the correct blend.

With each additional flowmeter, ratio controller, and control valve, another component can be added to the blend. As the system operates purely on a volume basis, constant quality output will be obtained only from constant quality components.

Acknowledgement: The author would like to thank the following for their generous help in discussing blending philosophy and in providing descriptions of the various systems:—S. W. J. Wallis and J. M. Keating of British Petroleum Trading Ltd., J. R. Moore and P. Stone of Fisher Governor Co. Ltd., H. H. Idzerda and A. C. H. Borsboom of Koninklijke/Shell Laboratorium, Amsterdam, Dr. H. H. Rosenbrock of CJB Ltd., and E. J. Hillier of Dowty Rotol Ltd.

Automatic Inspection and Computation Reduce Reject Rate

Test and inspection make sure that the key characteristics of a product meet specifications. In the fabricating industries automatic evaluation got its boost from techniques and equipment developed to inspect missile systems. In raw materials processing it was made possible by plant-site analytical instruments. Automatic evaluation leads in the right direction since it creates interest in making manufacturing operations even more automatic. In every case it gives superior quality control records, clues to inefficient operations, etc. The case studies here include a numerically controlled production and inspection sequence, a system for testing electronic components, and process evaluation by automatic titration and pH controls.

ALBERT M. DEXTER
Pratt & Whitney Co., Inc.

This is a story of integrating the most modern automatic production techniques to achieve an end that could not be accomplished in any other manner. The sequence of operations and the equipment used are shown pictorially on the next two pages. The object is to produce a highly precise template. Although the problem discussed here is a very specific one involving the inspection of critical missile components, many of the techniques and equipment can be profitably employed by themselves or in simpler combinations to benefit commercial industrial production.

The integrated procedure

The engineering drawing specifications and machining instructions for the template are fed to a digital computer which is programmed to convert this information into the form required to instruct a continuous path numerically controlled milling machine.

But even a precise numerical milling machine cannot always produce the accuracy required, so the template is inspected on a tape programmed inspection machine. This machine is completely flexible and is well suited to the inspection of precise parts where the parts differ from one another. The output is a record of deviation along the template contour.

If the template contour falls out of tolerance, it may still be completely satisfactory if shifted slightly. In this system the required shift is determined by running the deviations from nominal through a least squares curve fitting routine in a digital computer. The output of the computer tells how much to rotate and translate the template to achieve the best fit.

The template is finally used on a universal inspection machine to inspect missile components. Since this machine is not tape programmed, but rather requires templates to set the gages, it is best suited to inspecting pieces which will be produced in quantity.

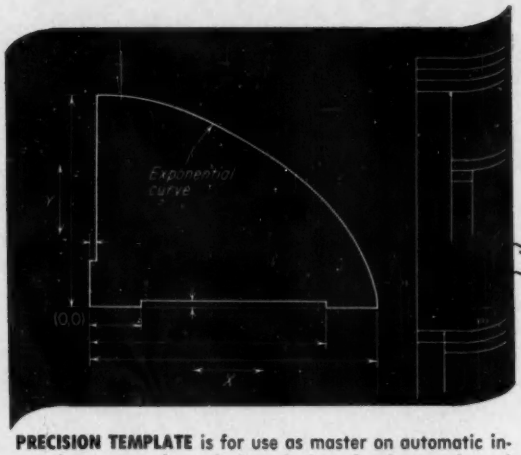
Lessons to be learned

First note the two types of automatic inspection machines. One is highly flexible using easily prepared tape to run it through its routine. But it is not fully automatic and is best applied where many different objects must be inspected since the inspection program can be quickly and cheaply altered.

On the other hand, the universal inspection machine for which the template is the master is fully automatic once the gages have been set, even including the data processing functions. It is a higher speed production type of machine, intended for the continuous inspection of identical workpieces where there are sufficient of these items to justify the expense of the templates.

Probably the most important concept introduced in this integrated system is that of improving accuracy and reducing reject rate by carefully examining the results of the template inspection operation. Normal practice would be to consider the (0,0) origin inviolate, and to base acceptance or rejection of the contour on this fixed set of coordinates. But actually the location of the origin is not known any more accurately than any other point and can be shifted if such a shift would improve contour fit. This important principle will undoubtedly be widely applied in the future by more completely analyzing inspection data.

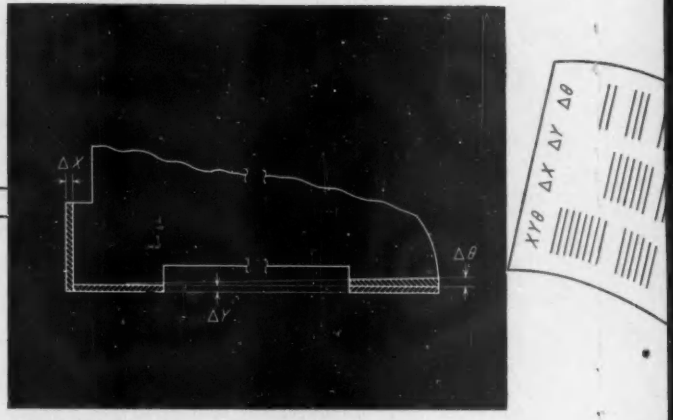
Precision template PRODUCED, INSPECTED, and IMPROVED by numerical control and computation



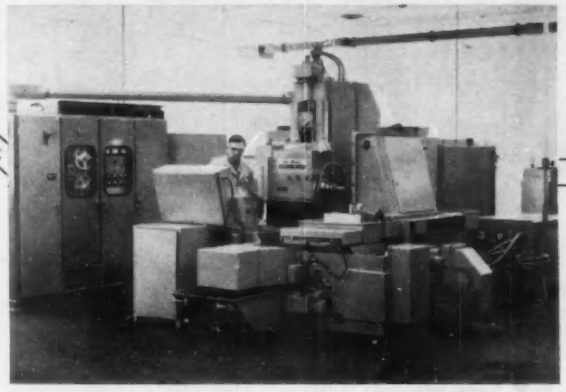
1 **PRECISION TEMPLATE** is for use as master on automatic inspection system shown in Item 8. Gage heads on universal contour measuring machine are checked against this master prior to inspecting missile components. The problem is to produce a template accurate enough for this purpose. The cycle begins by initially machining the template on a numerically controlled milling machine.

2 **BENDIX G15D COMPUTER** assists in preparing input data for numerical milling machine. Engineering drawing information in the form of point coordinates, line directions, radii, etc., plus machining instructions such as tool radius and permissible tolerance are coded into punched tape and fed to the computer. Then automatic machine tool programming routines such as Compac I or II or Flexpac take the input data and generate specific machining instructions in the form of incremental components and feed rates as required by the machine control unit. These machining instructions are recorded on punched tape.

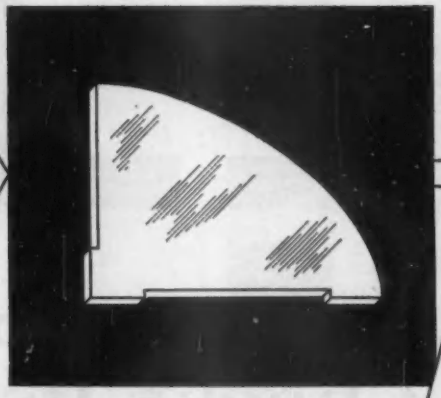
8 **UNIVERSAL CONTOUR MEASURING MACHINE** uses the precision templates as a master for setting the inspection gages. Actually two templates are required: one sets the gages that inspect the inside contour of the missile component, the other sets the outside gages. The machine has several gage heads one above the other that are first set against the templates and then swung against the piece to be inspected once it is mounted on the rotary table. The data processing system scans the gages in order, typing out deviations from nominal readings of both gages and computed deviation from nominal wall thickness. Once all the gages have been read for one angular location, the workpiece is automatically rotated a specified number of degrees and the operation repeated until the part is completely inspected.



7 **PART MODIFICATION** follows by shaving the template feet based on axis translation and rotation data supplied by the computer. The sum of the least square errors before and after modification shows a gain of at least five to one, resulting in improved accuracy of every template and no rejections to date. Even the largest templates are so accurate that all of the points fall within a plus or minus 0.001-in. envelope about the desired contour, and at least one has been produced where all points fell within a plus or minus 0.0001-in. envelope.



3 **NUMERIC-KELLER** is a three-axis horizontal spindle milling machine controlled by a Bendix continuous path system. It accepts the punched tape prepared by the computer, performs a roughing operation around the template shown in Item 1, and fine finishes the template on the feet and contour. The numerically controlled milling machine is accurate within a few ten-thousandths of an inch.



4 **MACHINED TEMPLATE** as it leaves milling machine ready for inspection. Templates have ranged in size up to 4 ft x 3 ft x ¾ in. The precise accuracy specifications require that the inspection machine and template to be inspected be housed in a temperature controlled room and allowed to remain there long enough to become temperature stabilized.

6 **TABLE OF DEVIATIONS** is then fed to Bendix computer programmed to perform a least squares curve fitting routine. Key point is to realize that the origin and coordinate axes established by the template feet are actually known no more accurately than the contour itself. Thus the computer program mathematically rotates the template and shifts it in the X and Y axes until the actual contour most accurately approximates the desired contour. Computer output is ΔX, ΔY, $\Delta\theta$.

5 **PROGRAMMED INSPECTION MACHINE** uses P & W Electrolimit numerical positioning system with a standard Trans-O-Limit linear differential transformer type of gage head in the machine spindle. The sensing head readout is calibrated in 10-microin. divisions. Template is oriented by its locating feet on the inspection machine table and is then automatically positioned so that a series of check points on the contour fall exactly under the center of the quill. At each inspection point the operator rocks the gage head by hand to achieve a minimum reading, thus making sure that the gage is normal to the contour before actuating the recording circuit. Deviation from nominal is recorded on a strip chart recorder and on punched tape.

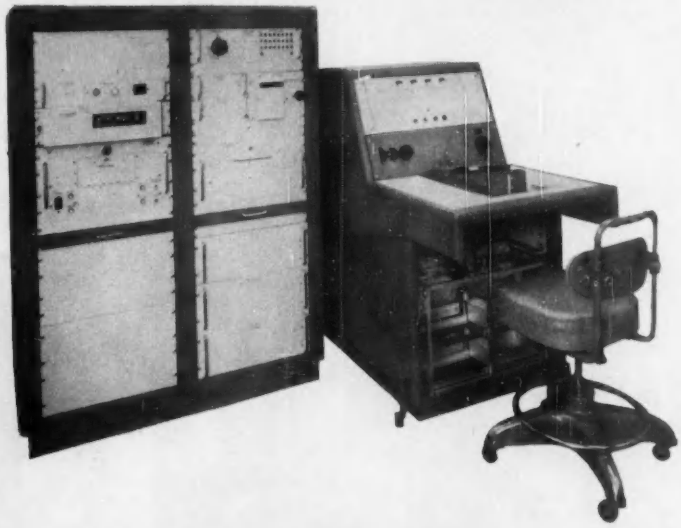


FIG. 1.
Fixed resistor tester, showing both electrical console and mechanical handling equipment

Fast Component Tester Checks Itself Too

THE GIST: Card programmed automatic component testers perform 100 percent incoming inspection for missile contractor. Digital equipments are self-verifying and check fixed resistors at 2,000 per hour and transistors and diodes at 500 per hour.

SAUL LISS, Kearfott Div., General Precision, Inc.

The two testers described here were designed to be as much alike as possible. This not only simplified fabrication, servicing, and operator training, but also made it relatively easy to extend the line to handle such items as variable resistors and fixed and variable capacitors. Standardization was not difficult to achieve from a mechanical standpoint, but the electrical equipment caused more trouble because of the large number of different electrical parameters involved in testing six different components. A measure of electrical standardization was achieved, however, by using standard digital circuitry.

This involves transducing all measurement parameters into a common digital terminology, Figure 2, so that standard digital comparators can be used. This way, programming the different modules to perform the different tests is simplified and in some cases unified. The key to success is in the preparatory circuits, the object being to reduce all test information (resistance, frequency, capacitance, voltage, etc.) to a single type of input to the analog to digital converter. Then each tester can use the same converter, in this case a solid state unit operating at 2,000 conversions per sec. The other input to the comparator is from the card reader programmer so that desired parameter value is compared with the measured value. Comparator output either feeds printing or card punching output equipment, or simply selects go/no-go lights.

Self-verification capabilities

When a program card is inserted in the reader, a series of self-verification checks is performed. These are also repeated at specified time intervals, depending on the number of tests to be performed on a component and the predicted reliability of the circuits. The fixed resistor tester self-checks itself every half hour, the transistor-diode tester prior to testing each component. In addition, resumption of power after a failure initiates a self-check cycle, and the operator can demand a self-check at any time. Scheduled self-checks in no way slow down the tester since they are performed during the transfer of a component into the test position.

In addition to checking circuit logic and mechanical operation, the selfcheck also verifies equipment accuracy against standard elements consisting of ultrahigh precision resistors in oil (accurate to 20 parts per million). These permit checking the measurement circuit within the test equipment tolerances rather than normal component tolerances. The standard resistors are housed in removable modules so that a spare can be substituted while the unit in use is calibrated in the laboratory.

Fault isolation during checking

If the self-check finds that a circuit or component is faulty, the equipment is programmed to stop and light a malfunction light on the panel. The fault isolation circuitry in the resistor tester electrical console (see Figure 3, top right module) is actuated by rotating the circuit check knob which isolates sequentially the precision power supplies, data conversion circuits, and digital comparator. Specific difficulties are then located by checking the relay voltages which have been brought to the front panel alongside the circuit check knob.

Difficulties in the mechanical handling console, Figure 4, can be isolated also. A pushbutton controlled subprogram causes all operating doors, chutes, and working and handling devices to operate sequentially. Any failure to operate properly is indicated by specific malfunction lights.

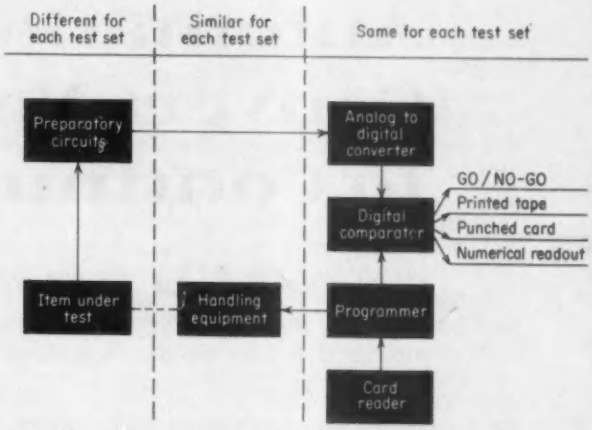


FIG. 2. Use of similar mechanical handling unit and identical digital circuitry makes it easy to fabricate different test systems.

Fixed resistor tester

Since the two testers are similar in concept, only the simpler of the two, the fixed resistor tester, will be described in detail. This unit can handle resistors from $\frac{1}{8}$ to 10 watts and from 5 ohms to 22 megohms. Test accuracy is about 0.1 percent.

When a punched card is inserted, the system is programmed and started. A totalizer keeps track of operating time so that the standard reference module can be replaced and checked at proper intervals. The equipment will accept either individual resistors or a card that contains 50 to 150 resistors, depending on size. The test components roll down a vertical zig-zag chute to a single feed contact mechanism which takes over and moves them into test position. The guide jaws and single feed mechanism can be adjusted to accommodate $\frac{1}{4}$ to $2\frac{1}{2}$-in. resistors.

When a test is completed, acceptable units are marked with a colored dot and deposited in an Accept bin; rejected units are dropped into High or Low bins. Each bin has its own counter for evaluation purposes.

A manual mode of operation is also available which causes the test cycle to stop whenever an out-of-tolerance resistor is measured, or after every resistor is measured, in order to monitor the converter display. Controls are provided for repeating the measurement or resuming the cycle. There is also a separate manual module in the electrical console, Figure 3, for handling any resistor configuration not suitable for automatic handling. In this mode the operator inserts the resistor and presses the button: the resistor is automatically qualified as low, go, or high. Rates of 1,000 per hour are possible with a solenoid operated foot switch. The same card programming is used for both automatic and manual modes of test operation.

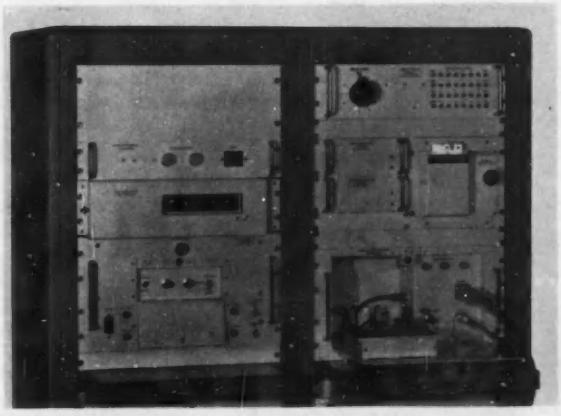
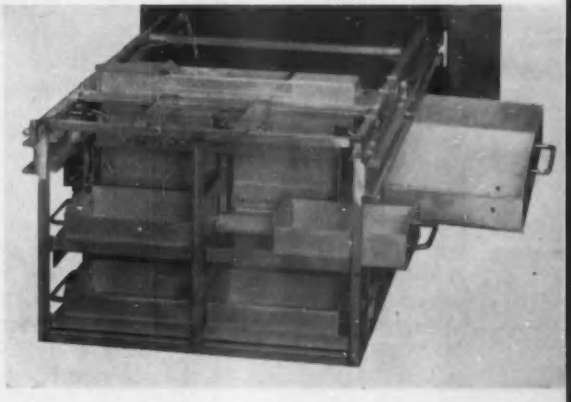


FIG. 3. Upper half of electrical console contains control switches for following functions: 1) go/no-go lights—on/off; 2) Nixie numerical readout—on/off; 3) self test—automatic demand; 4) manual retest for resistor in handling console; 5) manual advance for resistor in handler; 6) mode control—manual, automatic, or automatic with stop.

FIG. 4. Bin system rolls out for easy removal of tested components and to facilitate servicing.



Automatic Analyzers Convert Yeast Plant to Continuous Operation

Converting processes from batch to continuous operation has the potential goals of lower capital and operating costs, increased throughput, and better product quality. Here from England is an example of how economic rewards were gained by using a programmed sequence control, a pH control system, and automatic titrating apparatus at Distillers Co.'s 300 ton per week continuous fermentation yeast plant. Benefits: yeast production rate up 38 percent, manhours per ton down 44 percent, instruments cost less than for a comparable batch plant.

H. SHER, The Distillers Co. Ltd.
R. F. RODGER, Electronic Instruments Ltd.

Yeast production starts with the addition of seed yeast to a tank containing molasses and ammonia, the ammonia liberating nitrogen which together with the molasses feeds the yeast culture. Final product quality is governed by nitrogen content and pH. To control yeast throughput and quality, therefore, two variables are manipulated under guidance of two timed-shared analysis instruments operating in closed control loops:

- a pH control system manipulating sulfuric acid
- an automatic titrator manipulating ammonia.

Figure 1 shows how these two systems control the five-tank yeast production plant. The sixth tank is not controlled but is used to mature the yeast.

A punched steel-tape sequencing programmer controls the addition of fixed amounts of molasses, sulfuric acid, and ammonia into the vessels as the liquor passes continuously through them. While the programming system aids considerably in reducing manufacturing costs, of prime interest here are the two analytical control systems.

Growth control

To ensure that the yeast grows in its liquor at an optimum pH, a control system regulates the addition of sulfuric acid to all tanks. From each tank a sample stream of yeast liquor is pumped off through a sampling vessel fitted with pH electrodes. Stepping switch selectors sequentially connect, every 2.5 min, each set of electrodes to the pH controller input. The controller's electrical output is converted to a corresponding pneumatic signal which operates the sulfuric acid inlet valve on the tank being monitored. The valves are maintained in fixed position until changed by a new measurement.

Nitrogen-content control

In tanks *A* and *B* ammonia feed is not controlled, but the nitrogen content is recorded. Tanks *C* and *D* use an on-off control system, shutting off the normal ammonia flow when nitrogen content exceeds a preset value, thus preventing excess nitrogen buildup in the tanks. Nitrogen content in the final vessel, tank *E*, is more critical. Here a nitrogen measurement continuously controls the ammonia inlet flow. On tank *E* a self-balancing recorder registers the tank's nitrogen content. A control signal proportional to this value is read out of the recorder motor position into an electropneumatic converter. The resulting 3 to 15-psi output positions the pneumatic valve controlling ammonia feed to the tank. During titrations on other tanks, the recorder motor is locked—giving a constant pneumatic output until the next titration 30 min later.

Nitrogen content is measured by the second analytical control system, Figure 2, which performs a double titration in 10 min. A solenoid operated selector valve allows a sample to flow from each tank. Separate stepping switches select the tank coupled to the automatic titration equipment. Each tank is checked once an hour, except for tank *E* which is sampled every half hour to obtain more effective control over final yeast quality. A four-bank, 25-position stepping switch, operated by a thyratron pulse generator, sequences the titration procedure.

The first titration tells when the acid content of the yeast liquor has been neutralized by an addition of caustic soda. After connecting the sample to the automatic titrator, a sample inlet valve opens to a 50-ml sample vessel. The sample flows through the vessel and out to waste until a 10-sec timer closes the valve. Another valve then opens and drains the sample into a reaction vessel. Caustic soda enters a burette and is then titrated through a valve into the reaction vessel to neutralize the free acid.

To carry out the second titration—which determines the residual nitrogen content of the liquor in the tank—formalin is first added to the reaction vessel. The formalin combines with ammonia to release sulfuric acid from the residual ammonia sulfate which the yeast has not yet utilized. The burette is again filled to a 50-ml level with caustic soda. The amount of caustic soda released through the burette valve to neutralize the sulfuric acid is read by a travelling lamp and photocell head.

As the second titration nears its endpoint, determined by pH values, an anticipatory circuit in the endpoint detector slows down the run-in of caustic soda by energizing the burette valve for progressively shorter periods to give a drop-by-drop addition of titrant. Each valve operating pulse resets a 22-sec timer, the endpoint being signalled only when the burette valve has remained closed for a full 22 sec.

The "titration complete" signal advances the stepping switch to energize the reading motor which, through reduction gears and a leadscrew, drives the light and photocell readout head up the burette until the meniscus interrupts the light beam and the motor stops. The meniscus level shows how much caustic soda was used to complete the titration and therefore indicates nitrogen content. A precision potentiometer coupled to the motor shaft reads out the titration value with an accuracy of 0.25 percent. The whole cycle now repeats, since stopping the motor reverts the autotitrator sequencers to their reset position and advances the sample selector to connect the next tank to the analyzer.

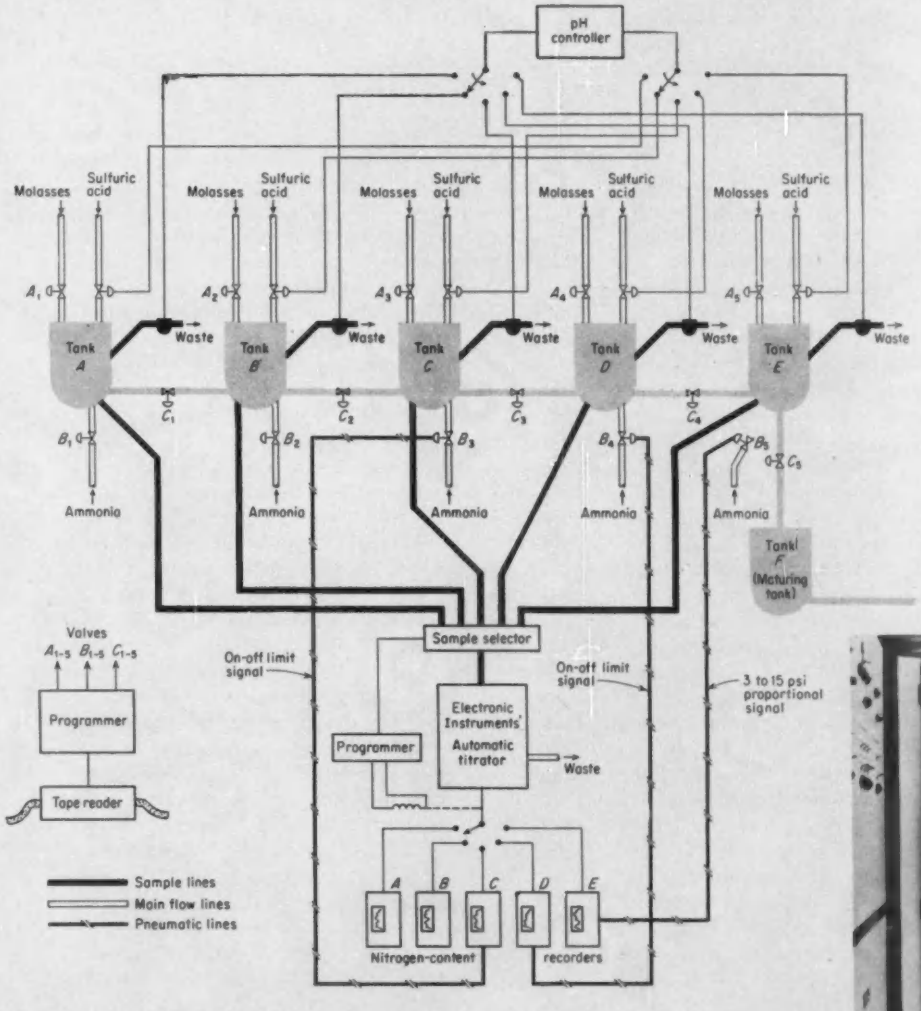
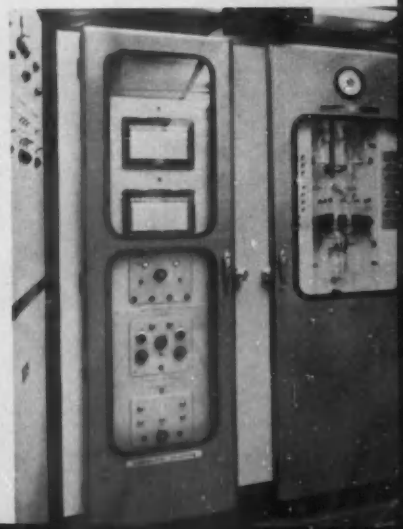


FIG. 1. Two time-shared analysis instruments operating in closed loops and a sequential programmer control the five-tank yeast plant.

FIG. 2. Automatic titration equipment in the plant control room. The cabinet at right houses the reaction vessel, burettes, and solenoid operated valves. In left cabinet are the recorders and sequencing gear and the pH detector for determining titration endpoint.



New Drives Sharpen Conveyor Synchronization

Often more time is wasted in getting material in and out of storage, in moving pieces from machine to machine, or in making sure that two parts arrive at the same place at the same time than is saved by automatic production operations. An automatic machine is useless if it has run out of raw materials or has no place to put its finished products. These problems have stimulated development of automatic materials handling techniques in such diverse fields as warehousing, mail sortation, airline baggage handling, and automatic lease custody transfer in the oil fields. This article tells how Plymouth increased positioning accuracy in a conveyor synchronization application. The next two articles describe a programmed manipulator for feeding a forging press and a bulk materials handling system in a brewery.

R. B. MAAG, The Louis Allis Co.

When the Plymouth-Detroit assembly plant of Chrysler Corp. was changed over last year to produce new unitized bodies, the 30 new conveyors needed were equipped with eddy current drives controlled by a new conveyor synchronizing system. This includes an amplifier in the discriminator output to increase the gain and thus the accuracy of positioning. Chrysler Corp.'s new assembly plant at St. Louis is also using more than 60 of these systems.

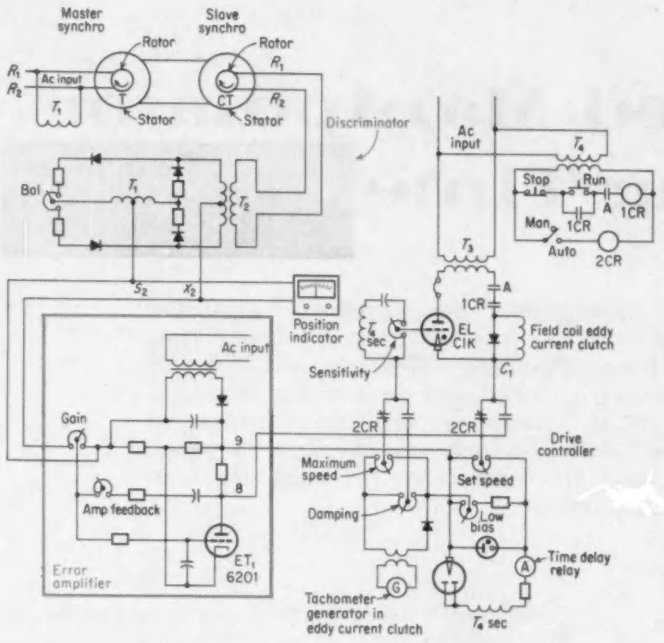
The Plymouth-Detroit plant is broken down into five areas: the body shop, where the various parts of the unitized body are welded together; a body preparation area, where the finished body unit is given a series of dips and bakes in preparation for painting; the paint shop; and the mating line, where the stub frame which carries the front suspension assemblies, engine, transmission, etc., is brought together with the main body line; and the final assembly line. The conveyor systems in each of these areas are synchronized independently to a master rate synchro signal. The individual conveyors within each of these systems are position synchronized to the conveyors just ahead.

Although there are some overhead hook-type conveyors in the plant, as in the dipping area, most of the body conveyors are the floor-type in which the bodies are carried by special dollies pushed by dogs on the conveyor chain. The pusher dogs are spaced evenly along the chain with enough space between the dollies so that assembly workers can work safely on the ends of the car bodies as the conveyor moves.

The transfer of cars from one conveyor to the next is done by overlapping the ends of the chains. Thus the conveyor chains must be rate and position synchronized so that the dog on the second conveyor will pick up the dolly just after it has been dropped by the dog on the first conveyor. If the second conveyor dog is too far ahead of the correct position, it will miss the dolly and a void will occur on the line. If the second conveyor dog is too far behind its correct position, the dollies may pile up and could cause damage to the car bodies.

Figure 1 is a simplified block diagram of a complete ac conveyor drive system including synchro position control accurate to better than 1 percent or plus or minus 3 in. for a 22-ft job space. The position error signal results from comparison of the position of a control transformer synchro on the following or slave synchro with the position of a transmitter synchro on the lead conveyor, or with master rate drive. The comparison is made by a ring demodulator or discriminator circuit. The excitation applied to the transmitter synchro is applied also to the discriminator circuit as a phase reference by a winding on the same transformer T_1. The amount by which the phase of the output voltage from the slave synchro varies from the reference phase is proportional to the position error. The slave synchro output is applied by way of transformer T_2 to the discriminator to produce a dc output signal proportional to the synchro position error. The polarity of the output indicates the direction of the synchro error and is positive if the slave synchro lags the transmitter and vice versa.

The new conveyor position controls at the Plymouth-Detroit plant also include the error amplifier



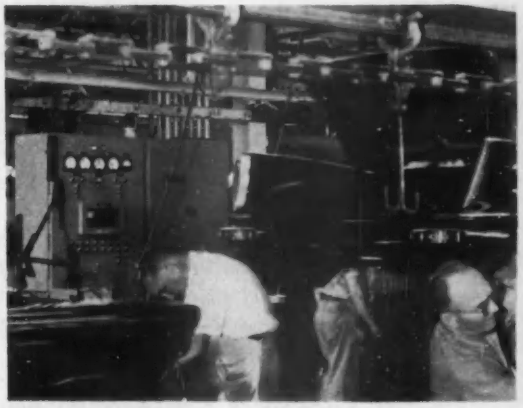


FIG. 1 (left). Simplified circuit of position control system. Output is current in control field of eddy current clutch. . . . FIG. 2 (above). Control cabinet for four-drive conveyor. Floor conveyor ends here, and car bodies are transferred to overhead conveyor to go to final assembly.

shown in Figure 1, which shapes the discriminator output signal for more efficient utilization by the input circuit of the ac drive controller and increases the sensitivity of the entire position control loop. The error amplifier incorporates negative feedback to reduce the sensitivity of the control system to transient disturbances. The ET_1 amplifier tube is biased so as to cut off the negative portions of the discriminator output signal and to amplify strongly the positive portions.

The output of the error amplifier is connected to a Louis Allis Ajusto-Spede drive controller so that it replaces the usual speed setting potentiometer. The drive controller provides thyratron control of the current in the field coil of an electromagnetic eddy current clutch which couples a constant speed ac drive motor to the conveyor. The Ajusto-Spede controller is the circuit at the right-hand side of Figure 1. The contacts on relay 2CR switch the input circuits from manual control by the speed setting potentiometer to automatic control.

In manual control the grid-to-cathode input circuit of the EL C1K thyratron sums the voltages across the sensitivity potentiometer, the maximum speed potentiometer, a portion of the low bias potentiometer, and the speed setting potentiometer. The sensitivity circuit determines the amplitude and phase of a small ac signal supplied by a secondary on auxiliary transformer T_4. This ac signal is biased by the dc signals from the other three potentiometers to control the firing point of the EL C1K in each cycle of the ac power supplied to the load circuit by T_3.

The low bias potentiometer is normally set just once to cancel the small negative bias of the firing point inherent in the EL C1K. When properly set it introduces a negative 3 or 4 volts into the grid cathode circuit which will make the thyratron just inoperative for a zero voltage setting on the speed potentiometer. Any positive voltage from the speed setting potentiometer will then cause the thyratron to fire and accelerate the conveyor until the feedback voltage from the tachometer generator in the eddy current clutch equals or exceeds the speed setting voltage. The drive controller will thereafter maintain a conveyor velocity such that the average voltage from the tachometer generator just cancels the speed setting voltage.

In the automatic mode the speed setting potentiometer is replaced by the zero or positive output voltage from the error amplifier. The relay 2CR also replaces the maximum speed potentiometer with the potentiometer marked "damping" because the input signal from the error amplifier is a series of dc pulses, so it is necessary to change the level of the feedback voltage.

The Ajusto-Spede magnetic clutch drive provides wide range, high response speed control with no commutators or slip rings in the control loop, and without high current rectifiers. The rectifier across the clutch coil in Figure 1 protects the thyratron anode circuit from high surge voltages.

Some of the conveyors have multiple drives in which small motors are distributed along the conveyor line to decrease the chain pull for a given load. This permits a smaller chain to be used than would be necessary if a single drive were used. It also permits a better load distribution on the conveyors, which often turn corners and go up or down inclines. The multiple drive conveyors are controlled quite simply by feeding the output of their single error amplifier to the input circuit of each of the drive controllers. Figure 2 shows a controller for a four-drive conveyor.

Programmed Manipulator Cuts Forging Time

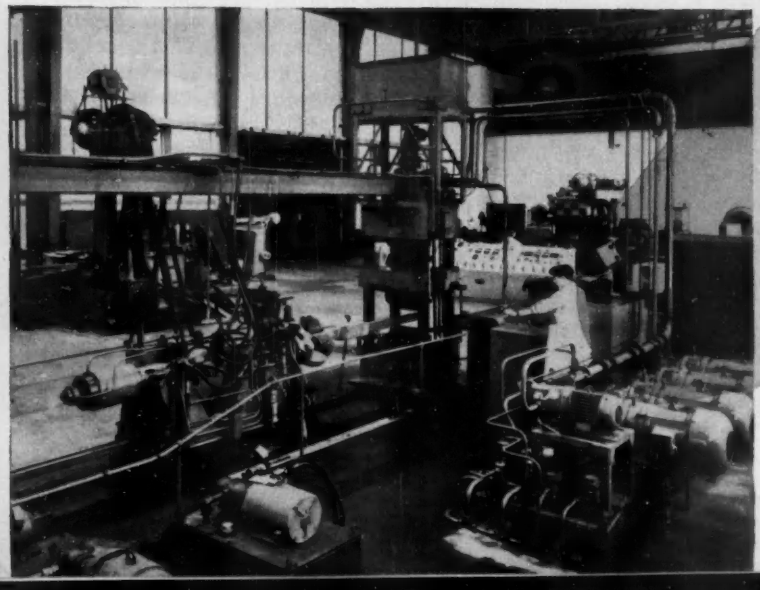
THE GIST: An automatic manipulator programmed by digital potentiometers and stepping switches has cut actual forging time in half on a 200-ton forging press. The larger time loss and high cost of reheating billets can be considerably reduced on complex forgings. The manipulator moves the billet through several preprogrammed steps, longitudinally and rotationally, on each pass through the press. Squeeze limits, billet height, and billet positions for each step can be preset independently for 30 passes.

P. N. BAKER and A. TOMLINSON
British Iron and Steel Research Association, Sheffield, England

Recent industrial studies showed that British forging equipment was slow and limited by inaccurate position control and poor coordination between presses and billet handling equipments. To raise productivity, the British Iron and Steel Research Association (BISRA) was faced with the choice of either augmenting existing forging press mechanization or leap-frogging to fully automatic forging and manipulating. The fully programmed forge was chosen, and 1956 saw the start of two parallel research programs. One was aimed at deriving mathematical working methods, from investigations of metal shaping, to permit complete programming of the forging operation in terms of the number of passes, the amount of squeeze on the billet, and the bites (distance the billet is withdrawn from the forge after each stroke) required to produce accurately forged shapes. The complementary second program was the development of an automatic programmable press and manipulator.

Figure 1 shows the world's first fully automatic 200-ton press and manipulator, which combines the results of both research projects. Calculations from knowledge of billet deformation give the constants for the forging program. These are then set up on the programmer in terms of billet longitudinal and rotational movements and upper and lower limits for the press crosshead on each pass. First results from this programmed forging system show a 2 to 1 speedup in forging time, typically demonstrated by the production of a final shaft shape accurate to $\frac{1}{32}$ in. (comprising three 20-in. lengths, each with different cross sections of 6 x 6, 4 x 4, and

FIG. 1. Programmed manipulator positions and rotates the workpiece into correct location between each press stroke of 200-ton forging press.



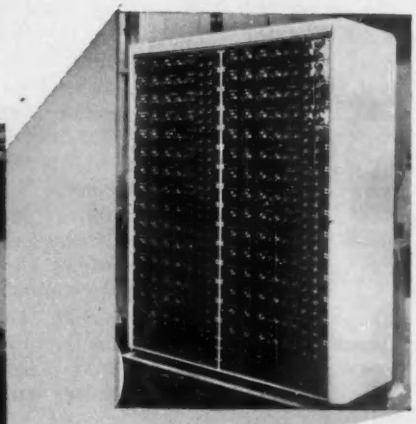


FIG. 2. Each panel of 30-pass programmer sets up seven variables.

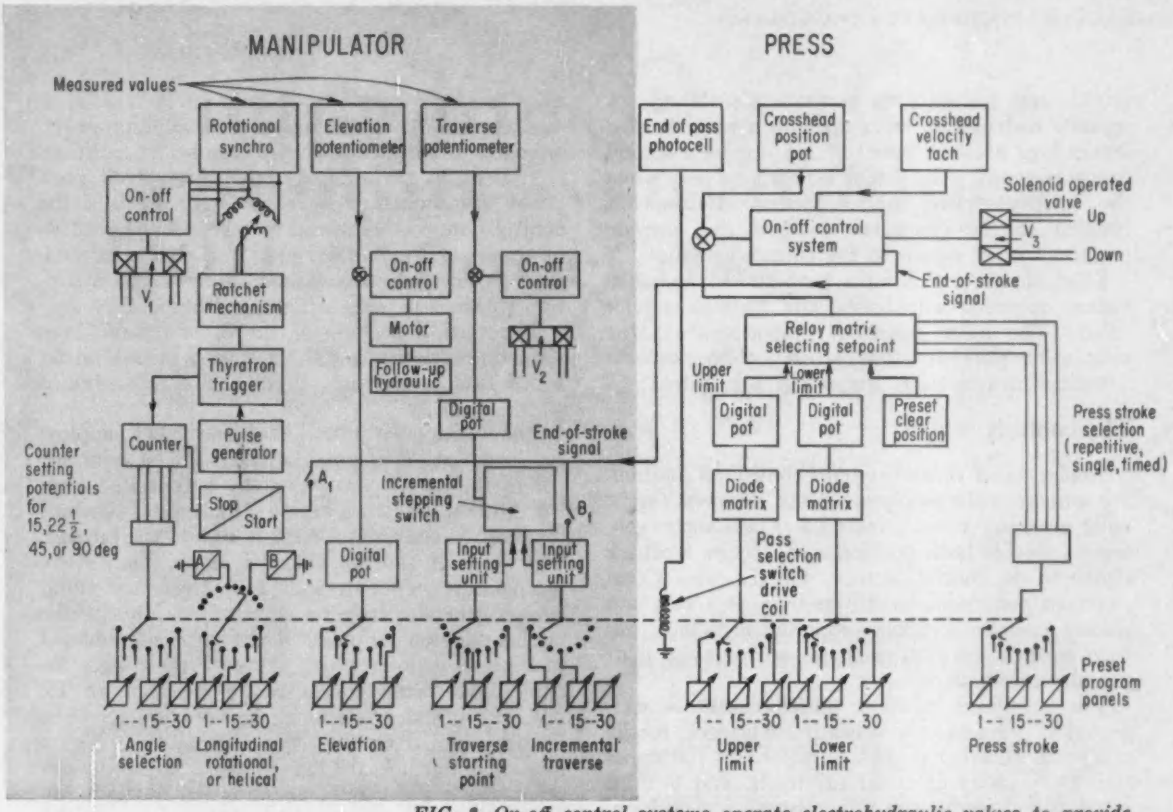


FIG. 3. On-off control systems operate electrohydraulic valves to provide manipulator and press motions. Two stepping switches determine the control system inputs: one provides equal increment stepping movements of the manipulator longitudinally; the other switches in new over-all programs.

3 x 3 in.) from an 8-in. square section ingot in 5 min. This compares with normal forging times for the same piece that are in excess of 10 min, plus the time and cost required for an additional reheat. (The metal cools below its workable temperature limit in less than the 10-min working period.)

The system

On-off control systems on both the press and the specially developed manipulator are coordinated by programmer circuits to provide three basic independent forging programs. In the longitudinal program the billet is progressively moved back in steps of 1, 2, 3, or 4 in. from the press after each squeeze. The second program is pure rotational, through preset angles of 15, 22½, 45, or 90 deg after each squeeze. The third program is helical forging, where both longitudinal and rotational motions are imparted to the billet simultaneously after each squeeze. In all programs, each step in the pass is initiated on the reversal of the press crosshead after it has compressed the billet. The manipulator repositions the billet for the next stroke during a 0.3-sec billet free time. An end-of-pass signal feeds new parameter values into the control system from the 30-pass programmer to start the next pass.

Figure 3 shows the basics of the combined electrohydraulic system. Four double pumps on the 200-ton press operate at 6,000 psi to provide a fast 14 in. per sec approach speed and a 3 in. per sec penetration during forging, resulting in a 1-sec total cycle time for a heavy cogging stroke. Solenoid operated valves control the crosshead direction and couple the press to a positioning control system.

The 1-sec cycle time determines the response requirements of the billet manipulator since its control systems must move a billet of 670 lb maximum weight through 30-deg rotational and 4-in. longitudinal motion within the 0.3 sec available for manipulation. For high response the 3,300-lb rail mounted carriage houses only the hydraulic cylinders and motors required for two of the three manipulator motions: billet rotation and elevation. Oil is supplied to the carriage by flexible pipes from two 1,000-psi floor mounted pumps—one for the billet elevation system and the other for billet rotation, ingot gripping, and a detent mechanism. This second pump also powers the longitudinal motion through a rack and pinion at the carriage rear.

Rotation of the billet is controlled by a solenoid operated valve which provides on-off control for a geared hydraulic motor driving a ring gear concentric with the billet jaws. Due to deadband in the on-off control system and the varying inertial loads of different billet sizes, mechanical locking

mechanisms are used for accurate positioning. A separate hydraulic cylinder operates a roller headed detent into notches spaced at 22½ deg on a second concentric ring. The detent is energized only when the solenoid valve shuts. Synchro transmitters coupled to the concentric toothed ring provide positional input signals to the control system.

Billet elevation is from a proportional hydraulic system operating a hydraulic ram through a pilot valve. The billet height is proportional to the pilot valve position. The on-off system positions a mechanism coupled to the proportional valve.

The controls

Similar on-off control systems control all positioning actions on the manipulator and the press except billet rotation. Potentiometers and tachometer generators provide both position and velocity feedback signals to the control circuits. On the press a cam corrected potentiometer driven through a rack and pinion generates a voltage proportional to the crosshead position. A tach generator on the same shaft provides crosshead velocity.

The crosshead position potentiometer is connected as one arm of a Wheatstone bridge. In the other arm two digital potentiometers set the upper and lower limits of crosshead travel, and a third rotary potentiometer sets the crosshead rest position, clearing it of any billet manipulations within the jaws. All three potentiometers are wired in parallel, and a relay matrix connects one of these three setpoints to a 400-cps differential error amplifier. The other amplifier input is from the crosshead position potentiometer. After phase rectification the dc amplifier operates a differential relay to energize either the up or down solenoid operated hydraulic valve on the press. As the crosshead approaches its desired position, velocity feedback from the tach takes over control to provide an anticipatory switch-off of hydraulic power and allow for crosshead inertia.

Alternative relay connections permit repetitive, single, or timed stroke operation of the crosshead by switching in new setpoints when relays signal that the crosshead has reached its desired position.

Each of the digital potentiometers setting the upper and lower limits consists of a selector switch, a diode matrix, and a binary resistor chain. Nine relays vary the tapping of 18 resistors. The relays switch resistors in and out while maintaining the total resistance of the chain constant. The diode matrix converts the decimal input value to binary to energize the appropriate relays. The upper and lower limits of squeeze are set in inches and fractions of an inch on the programming panels, Figure 2, by means of coarse and fine dials.

Similar control systems on the manipulator use digital potentiometers to provide billet height and traverse position setpoints. Using the same on-off differential relay type of control system, the traverse system has an additional feature by which the carriage can be progressively withdrawn in 1, 2, 3, or 4-in. steps. This is done by an extra stepping switch arranged to advance a limited number of positions equivalent to the desired step. After each press stroke this switch feeds a new setpoint into the control system. Additional switches set the position of return of the carriage after completion of each pass. Velocity feedback helps control carriage position within ¼ in. over a travel of 100 in.

The vertical position of the billet remains constant during a pass and is set from a potentiometer scaled from 0 to 8 in. Billet height is positioned within $\frac{1}{16}$ in.

The control for rotation of the billet employs synchros instead of potentiometers. The error signal to the on-off control system is generated from the position difference between transmitter synchros mounted in the control console and on the carriage. The setpoint synchro rotor is set by an electromechanical ratchet device. Line frequency pulses from a generator trigger a thyratron to advance the ratchet one step per pulse. These pulses are summed in a preset counter which shuts off the trigger circuit. Four cutoff counts can be selected for 15, 22½, 45, or 90-deg rotational steps. The final pulse in each count resets the counter after each stroke on rotational and helical forging. Rotation of the setpoint synchro generates an error signal which energizes the solenoid operated hydraulic valve.

Programming

The experimental programming unit has dials on 30 identical panels which allow the information for each pass to be set up for press crosshead travel, type of crosshead operation (repetitive or single stroke), manipulator longitudinal position at the start of each pass, incremental feed or bite between strokes, angle of rotation between passes, manipulator height, and type of manipulator motion.

Pressing the start button connects all energized switch positions on the first pass panel to the appropriate digital potentiometers as their setpoint inputs. In the subsequent operating sequence the press crosshead first moves to the rest position, and the manipulator raises the billet to maximum height prior to positioning. After positioning the billet correctly in the longitudinal and rotational plane, the workpiece is then lowered to the correct forging height, and the press makes its first stroke, descending to its preset lower limit. After each crosshead reversal the manipulator moves the workpiece progressively to a new position. This continues until the end-of-pass signal returns the crosshead to its rest position and advances the program selector to switch the several control systems to the second pass input information. To minimize time delays in transmission through the stepping switches, the switch controlling longitudinal incremental feed is advanced during the down stroke, allowing the new setpoint to be available on the up stroke.

Automatic Vacuum System Pipes Bulk Materials

THE GIST: When William F. Koelle Sons, consulting engineers from Philadelphia, tackled the job of designing a modern brewery for a South American company, they turned to Fuller for a pneumatic grain handling system that would be both foolproof and automatic. The system which evolved and its custom-built control panels are described on these two pages.

CARL H. BAST, Fuller Co.

Pneumatic conveying systems for moving dry bulk materials, such as cement, fly ash, grain, sugar, and other granular or powdered products, have served industry for over 40 years, but the application of automatic controls to these systems is of a more recent origin.

A typical example of a well instrumented modern installation is the grain handling facility recently installed at the Backus & Johnston Brewery in Lima, Peru, and shown schematically in Figure 1. Here, two vacuum-type pneumatic systems, designated the unloading system and the reclaiming system, provide clean, safe transfer of three brewers' grains: whole malt, rice, and black malt.

Unloading system

Whole malt arrives at the plant in bulk trailers; rice and black malt, in bags. There are 14 storage silos. The whole malt is sucked from the trailers and delivered to any one of 10 silos at the rate of 1,300 bushels per hr. Rice is picked up at a bag dump hopper and delivered to any one of the four remaining silos at a rate of up to 35,000 lb per hr. This unloading system also permits recirculation of the rice, i.e., withdrawing it from any one of its four silos and returning it to the same or another rice silo. Black malt, also unloaded from a bag dump hopper, goes directly to a single scale hopper in the brew house. All unloading operations are initiated from a single panel called the unloading control panel, but the flow path for the black malt is established on a second, or main, control panel. Figure 2 illustrates both panels. Note that the storage silos are shown on both, but that the piping differs. On the unloading panel only the lines into the silos and the recirculating lines are shown; lines from the silos to and through the reclaiming system are shown on the main control panel.

Reclaiming system

Both whole malt and rice are reclaimed from the storage silos and delivered to their respective scale hoppers in the brew house. Then the grains, along with the black malt, pass by gravity through scales, polishers (for the whole malt only), and mills to their respective holding hoppers below. These operations are programmed on, and controlled from, the main control panel. While the brew house now has only four scale systems (one for rice, two for malt, and one for black malt), the main panel is designed for seven (two for future malt and one for future rice). Beyond the scale hoppers parallel flow permits simultaneous scale operation.

Controls

Custom-built by Fuller Co. to match their pneumatic conveying systems, the graphic control panels provide for smooth operation of both systems. Within the cubicle behind the main control panel, a 3-kva control transformer supplies the necessary control power, and a separate circuit breaker panelboard protects all control circuits. In addition, each panel has a key-lock selector switch and lamps to indicate whether control power is on or off. All motorized pipe switches and turnheads are interlocked so that a system cannot be started while its pipe switch or turnhead is in the process of repositioning; conversely, when a system is already working, its pipe switch or turnhead cannot be repositioned. Alarm horns on both panels signal the operator that a storage silo, scale hopper, or holding hopper is full.

A multiple-point strip chart recorder (upper right on the main control panel) records the time during which a reclaiming valve is open beneath one of the

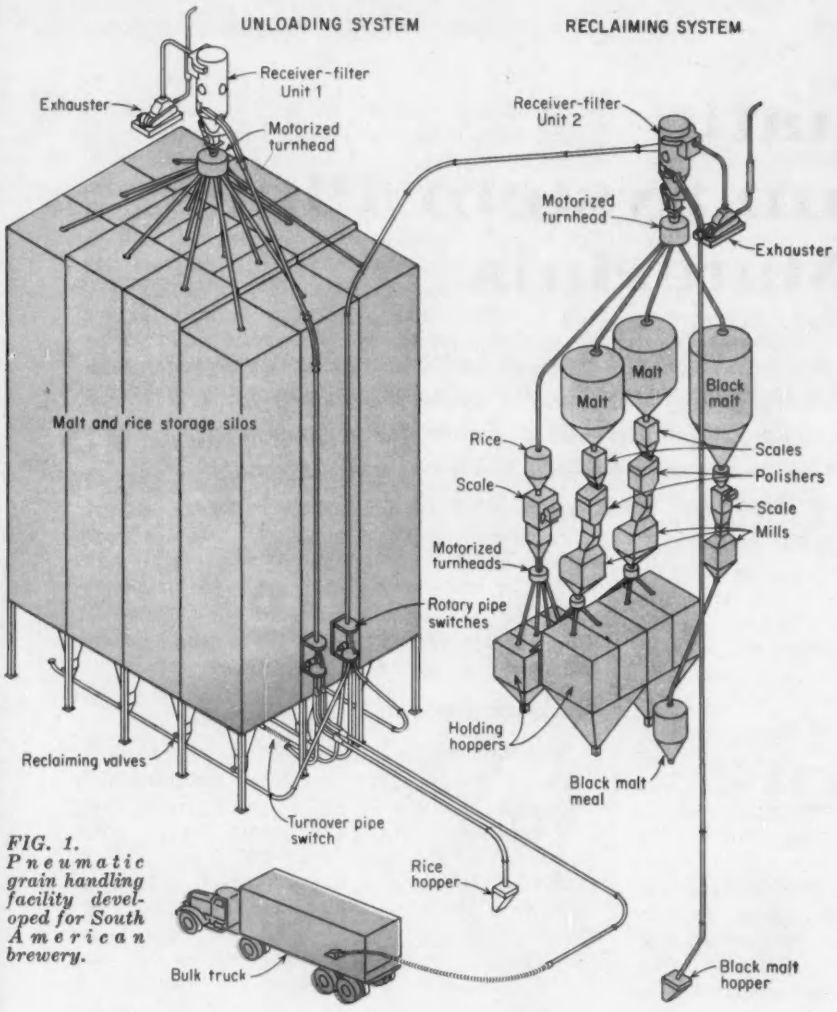
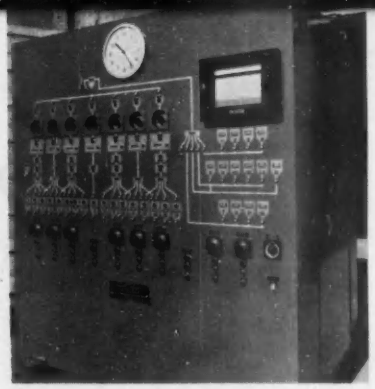


FIG. 1. Pneumatic grain handling facility developed for South American brewery.



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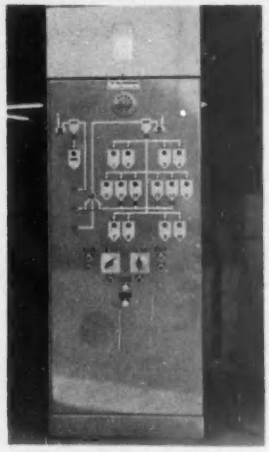


B

FIG. 2. Custom-built panels are: A—the main control panel and B—the unloading control panel.

malt storage silos. The actual open period of such a valve is controlled by a dial-set timer on the front of the main panel. The valves automatically close at the end of this preset period.

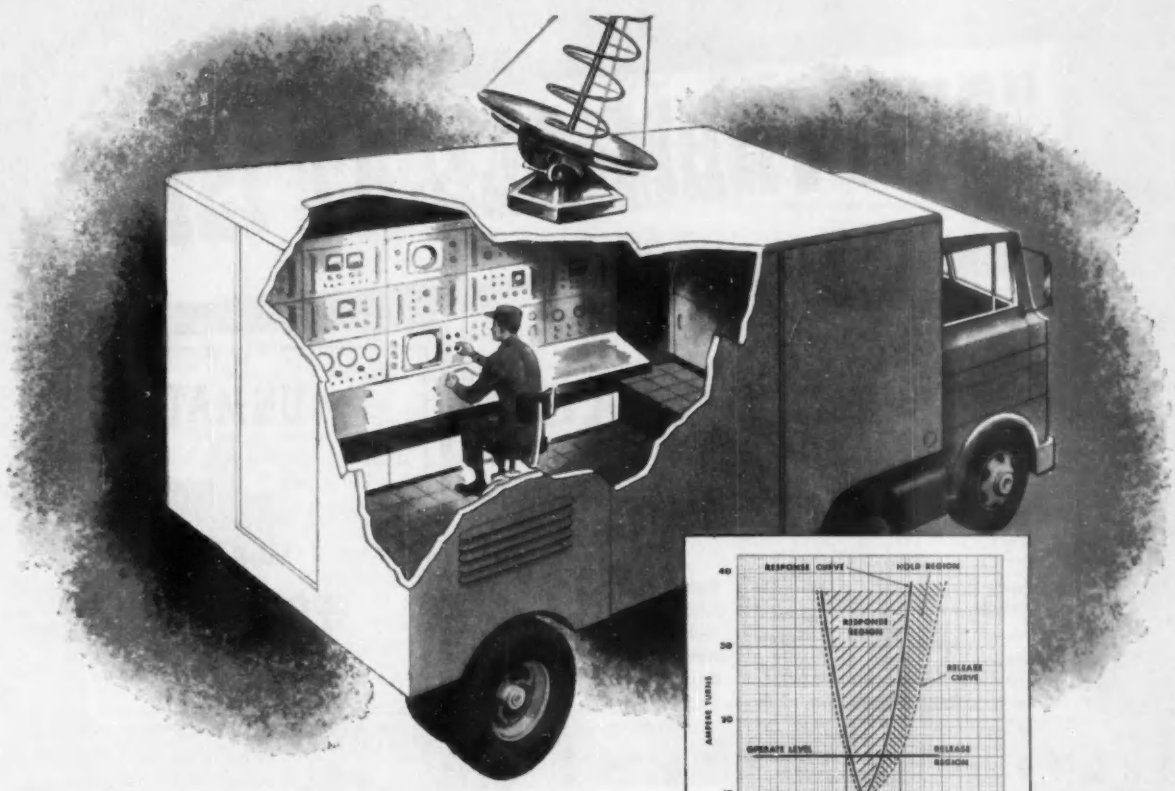
Two other important instruments on the main panel are the scale batch counters and the scale batch reset counters. Each of the seven scales has continuous batch counters which provide a totalized count of batches passing through a given scale. A locking arrangement allows only authorized personnel to zero these counters. Thus total batches are recorded over a given period, and this record becomes part of inventory control.

Each of the seven batch reset counters counts out a number of preset batches. After the required number of batches has been counted, the scale, milling, and polishing system shuts down automatically. Each time the system is restarted, the counter resets to its previous setting. This setting can be any number of batches up to a maximum of 400.

As an additional safety feature, oil motion switches are used on the feeders beneath the receiver-filter units. Their function is to open a circuit and shut down the system if for any reason the feeders stop.

Operating restrictions

This grain facility, like most materials handling systems, has a number of operating restrictions. Some of these were demanded for reasons of safety, others by economical considerations. For instance, the unloading and recirculation of rice cannot be performed simultaneously since these operations time-share a single receiver-filter unit. Rice cannot be recirculated and reclaimed at the same time because these operations time-share a common line beneath the rice storage silos. Nor can reclaiming and black malt unloading be done at the same time, because here again the operations use the same receiver-filter. These are examples of restrictions imposed by economic considerations. On the other hand, to assure safer operation, materials unloaded from the truck position cannot accidentally be delivered to the rice storage silos nor can rice be delivered to any of the malt silos. Likewise, material reclaimed from the malt silos can be delivered only to malt scale hoppers in the brew house, and material reclaimed from the rice silos can be delivered only to rice scale hoppers.



WURLITZER

DR-5 RESONANT REED RELAY

A reliable miniaturized relay featuring anti-vibration design and application flexibility

This new Wurlitzer Reed Relay incorporates shock and vibration resistance, zero mechanical coupling to support, and closely controlled response and hold regions.

Twin reed configuration based on tuning fork concepts makes the Wurlitzer Reed Relay highly resistant to false operation from shock or vibration.

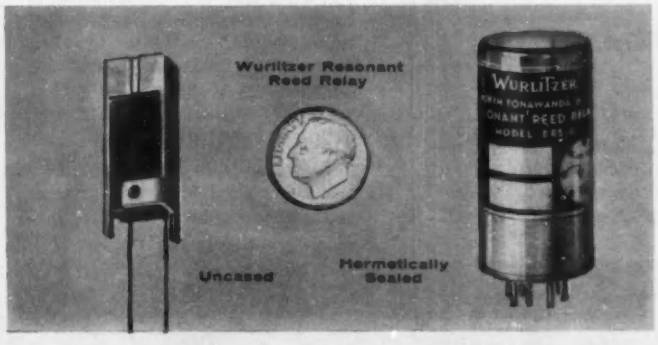
Sensitivity is less than 1.0 milliwatt.

32 channels at 4% increments between 300 to 1000 cps.

Frequency variation is less than ½% from —60°F to +150°F.

Has application in:
- Frequency Sensing and Measurement
- Selective Tone Communication and Control Systems
- Frequency Generation
- Controlled Sequence Contacting Applications
- Speed Control
- Ground Station Telemetering

Available in uncased, hermetically sealed, and plug-in models for frequency range of 300 to 1000 cps. Other frequencies available on special order.



Inquiries Invited

ELECTRONICS AND DEFENSE PRODUCTS DIVISION
THE WURLITZER COMPANY
North Tonawanda, New York

WURLITZER Research Engineering Production

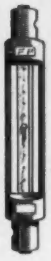
CIRCLE 199 ON READER SERVICE CARD

CIRCLE 201 ON READER SERVICE CARD→

"SEE THEM ALL AT ISA"

Booth 1534

ROTAMETERS



#2700 FLOWRATOR METER

Push-down, pull-up and this flowmeter with the snap-in tube is all set to go. Has the amazing tempered metering tube that takes 50% higher operating pressures. Unequalled convenience and economy saves users 50 to 75% on inventory.

!NEW!NEW!NEW!

Minirator

METER

The very finest meter for low flows it has ever been this company's pleasure to announce. Choice of 1½" scale to fit the tightest crevice, or 4" scale for unparalleled easy reading. Needless to say, this gem of a meter sports the famous F&P snap-in metering tube!

Magnarator

METER

Stamp-out flowmeter extensions with the Magnarator! No pipe turns . . . no recessed areas where products can congregate. Not merely an indicator, but a linear pneumatic transmitter as well!

Dial Indicator

METER

Makes the popular armored flowmeter more useful than ever before. Magnetic coupling converts float position to pointer position on a horizontal segmental scale of the very latest design.

UNMATCHED

FOR ACCURACY

The process accountant's friend

Unequalled accuracy over the widest range of flow! Unparalleled selection of transistorized readout devices.

Is it any wonder that the Fischer & Porter turbine meter is the natural choice of the cognoscenti for feed to batch processes . . . for in-line blending . . . for "cash-register" metering . . . and other demanding jobs?

It is a friend to all who need precise flow information

MAGNETIC FLOWMETER

AMAZING

An unobstructed length of pipe that measures the flow of even the least conductive fluids by the invisible magnetic field! Extends the range of accurate flowmetering to heretofore unbelievable limits.

YOUR ATTENTION INVITED

to the new *fully transistorized* indicator-recorder for the above-mentioned magnetic flowmeter.

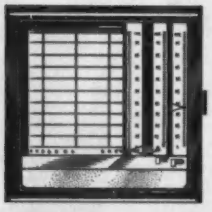
NEW

ELECTRONIC INSTRUMENTS

Have you seen the Compatible Transmitter?
Have you seen the Electronic Indicator-Recorder?
Have you seen the Electronic Controller?
Have you seen the Electronic Control Station?

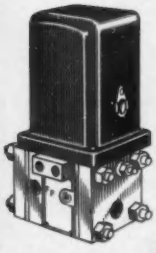
When you see the new F&P electronic control system you will find that the full promise of electronic control can at last be realized!

You can SEE the system now. You will be able to put it to work in your plant the very minute that field tests are completed. These tests are the most extensive and rigorous that we have ever devised. When our electronic instruments are released for your use, they will have been proved in actual operation.

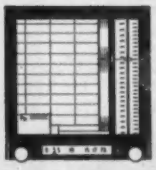


It is the determination of the house to send out nothing but what is of the highest possible quality and dependability.

PNEUMATIC INSTRUMENTS

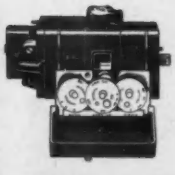


DP TRANSMITTER
53P CONTROLLER
MINIATURE INSTRUMENTS
TEMPERATURE AND PRESSURE
BELLOWS METER



With all due modesty we direct your valued attention to the estimable selection of F & P pneumatic control instruments available for your delectation.

No mere flowmeter manufacturer, WE ARE AN INSTRUMENT COMPANY! We offer instruments to measure not merely flow, but temperature, pressure, level, density, viscosity, consistency . . . a veritable panoply!



We have instruments to convert such measurements to accurate pneumatic signals . . . to populate the control panel itself . . . a selection so wide, deep, and varied as to make the head swim and the spirits cry out.

May we be so bold as to suggest that in our collection you will find an instrument for every kink in the knottiest of control loops?

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WARMINSTER, PENNSYLVANIA

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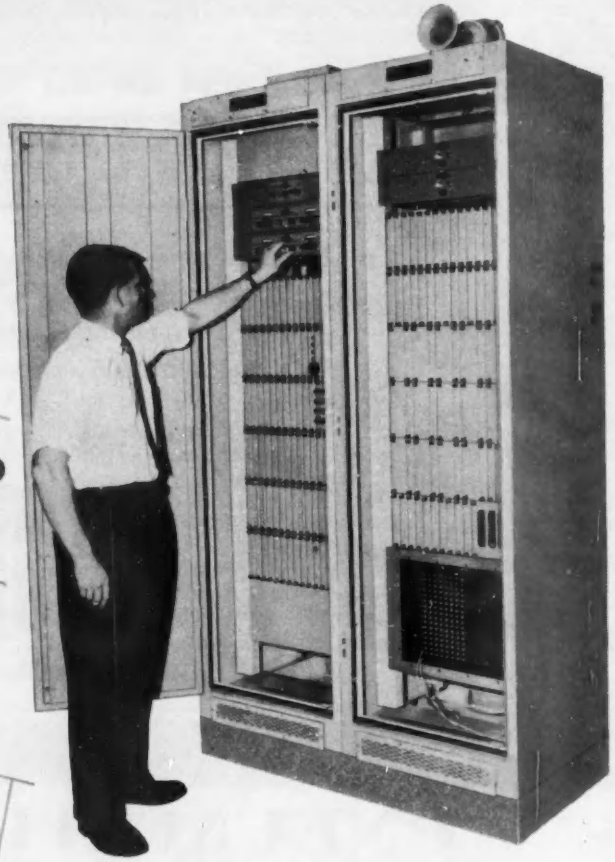
KEY to functions performed by Bailey 700 Systems

A — Analog **A/D** — Analog and Digital
D — Digital s — sense and measure
d — display (indicate, record and/or log)
m — monitor (scan and alarm)
p — produce stored information for future use (tape, cards) c—compute r—control

● Installed ● On order

LOCATION	TYPE	FUNCTIONS
1. Chelan Co., Wash.	D	sdm
2. Chelan Co., Wash.	D	sd
3. San Francisco	A	sdc
4. Salinas, California	A	sdc
5. Los Angeles	A	sdc
6. Glendale, Ariz.	A	sdc
7. Alameda, N. M.	A	sdc
8. Amarillo, Texas	A/D	sdmc
9. Smithers Lake, Tex.	A	sdr
10. Orange Co., Tex.	A/D	sdmcr
11. Bronte, Tex.	D	sdm
12. Sioux Falls, S. D.	A	sdr
13. Oklahoma City	A	sdc
14. Harrah, Okla.	A	sdc
15. Muskogee, Okla.	A	sdc
16. Lafayette, La.	A	sdc
17. Jackson, Miss.	A	sdc
18. Cleveland, Miss.	A	sdc
19. Memphis, Tenn.	D	sdm
20. Paducah, Ky.	D	sdc
21. Sullivan, Ind.	A	sdc
22. Graham, W. Va.	A	sdc
23. Ashtabula, Ohio	A	sdc
24. Monroe, Mich.	A	sdcr
25. Rochester, N. Y.	A	sdc
26. Ludlowville, N. Y.	D	sdmp
27. Buchanan, N. Y.	A	sdr
28. Fairless Hills, Pa.	D	dm
29. Wilmington, Del.	D	dm
30. Washington, D. C.	D	dp
31. Hamilton Twp., N. J.	A	sdr
32. N. S. Savannah	A	sdr



BAILEY 700

ANALOG AND DIGITAL SYSTEMS IN ACTION

Installed or under construction, Bailey 700 Analog and Digital Systems are IN ACTION TODAY from coast to coast, providing integrated instrumentation systems accurately tailored to specific needs.

Note the variety of functions performed in these installations. Basic ingredients of all are electronic modules housed in standardized electrical cabinets, as shown here. This permits any combination of control, information or computing system elements to be combined and expanded as required to perform specific functions in individual installations. Wiring and maintenance is simplified —operator's console is freed of bulky equipment.

Ask your local Bailey engineer to arrange a visit and demonstration of a Bailey 700 System located near you, or at Cleveland. Or get IMMEDIATE details on the installation of greatest interest to you, by TWX—just jot down the number of the location you select on message form below and hand to your secretary. Reply will be transmitted at end of your message.

G153-2

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PLS SEND 700 SYSTEM DETAILS FOR LOCATION_____. PROCEED IMMEDIATELY WITH REPLY AT CONCLUSION OF THIS MESSAGE.

Name_____ Title_____

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BAILEY METERS

NOW— CHANGE VALVE TRIM IN 15 MINUTES

New Leslie Cage Trim Control Valve is Designed for Today's Use and Tomorrow's Changes.

Here's a control valve designed in steel and alloy steels that offers new assurance the valve you initially specify and install *will always fit an application*—even if changes in plans or future system changes might ordinarily call for complete valve replacement.

The new Leslie cage trim valve allows complete trim inspection in 15 minutes without removing the valve from the line. You can also switch valve action or size of actuator. Or, change valve characteristic or trim materials at will with an inexpensive interchangeable trim kit that reduces spare valve and valve parts inventories. Cage trim cuts maintenance and system modification costs to the bone—it's the kind of valve that makes foresight almost as good as "hindsight".

For sizing and capacity data on cage trim control valves, write for Bulletin or contact your Leslie Engineer—he's listed under 'Valves' or 'Regulators' in the Yellow Pages.

LESLIE **Leslie Co., 722 Grant Ave., Lyndhurst, New Jersey**

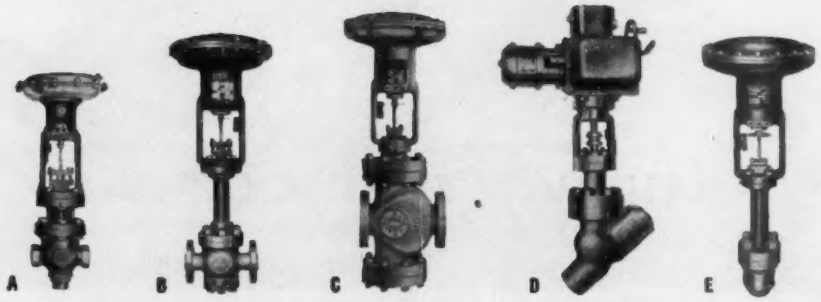
A Unbalanced valves up to 2500 lb ASA ratings.

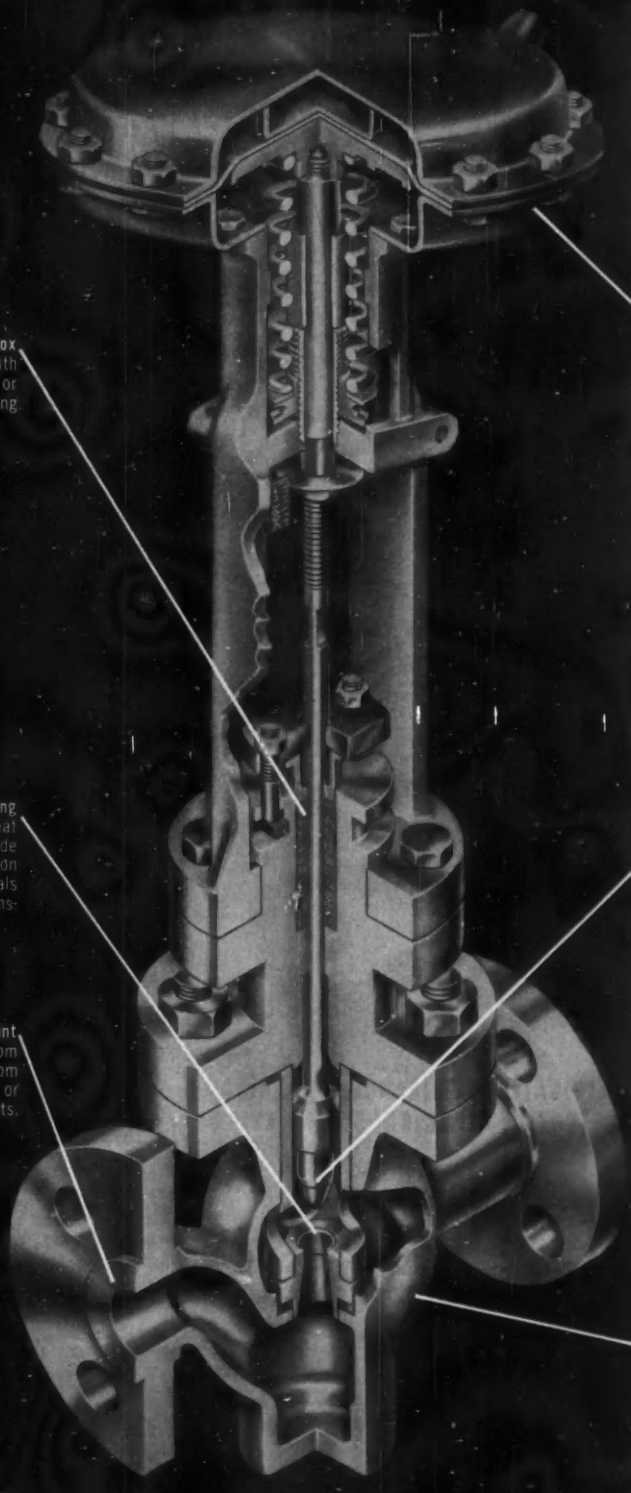
B Piston balanced valves up to 600 lb ASA ratings.

C Double seated control valves to 600 lb ASA ratings.

D High pressure-high temperature control valves.

E Angle body control valves.





Flanged, thru-bolted stuffing box — no lubricator needed with Leslie Lubrisoft® or Teflon V-Ring packing.

Actuators for normally open or normally closed valves with 35, 55, 85 and 135 square inch effective areas.

Long-Life, Stellite seating surface on renewable seat insert for steam service. Wide selection of alternate corrosion and erosion resistant materials for other applications.

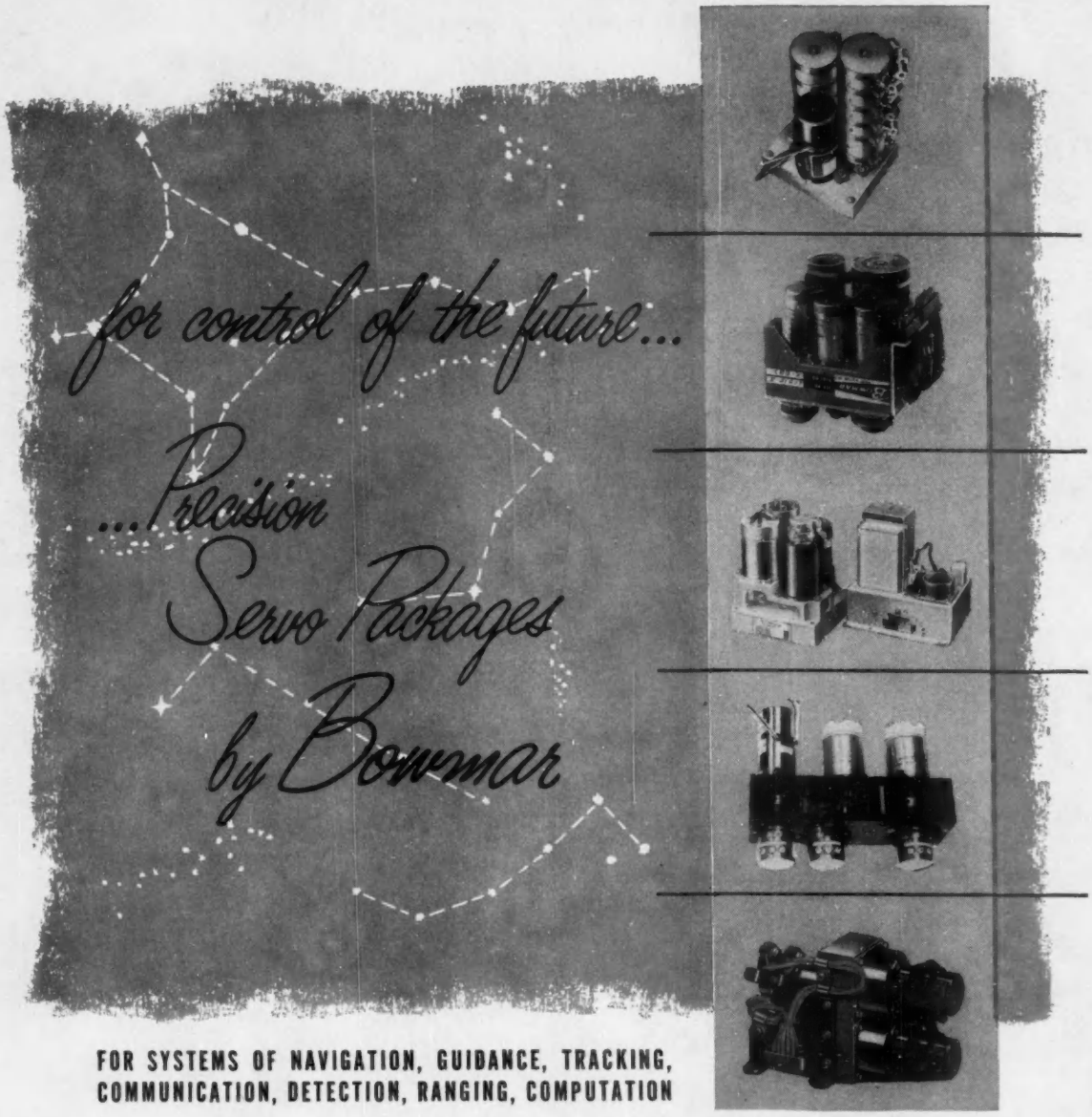
Interchangeable inner valve shapes and materials — choice of needle plugs, V-port, quick opening, micro taper.

Corrosion-erosion resistant materials in ASA rating from 150 to 2500 lbs. Select from a wide line to meet present or future system requirements.

High Capacity Body — any end connections in ½ to 3" sizes.

TRADE LESLIE MARK

REGULATORS and CONTROLLERS



FOR SYSTEMS OF NAVIGATION, GUIDANCE, TRACKING, COMMUNICATION, DETECTION, RANGING, COMPUTATION

Original Bowmar concepts in servo design and packaging are playing an important role in space navigation to make "way-side" landmarks out of celestial bodies.

Achievement of these objectives becomes more evident as the nation's leaders in space and flight control systems increasingly utilize Bowmar's collateral engineering skills, production facilities, and servo packaging hardware.

With strong accents on **reliability,** Bowmar has step by step improved the state of the art in precision control, guidance, computation, and communications packages while contributing to extraordinary reductions in system weights and sizes.

Bowmar skills have been demonstrated repeatedly in systems for many of the nation's most important aircraft, missile, and rocket programs. This has been achieved by Bowmar's knowledgeable grouping or packaging of components into complete functional assemblies, ready to perform system **thinking processes.**

These engineering skills and expanding facilities are readily available to help reduce system weight and size while improving reliability.

Bowmar's technical and administrative staffs welcome the opportunity to demonstrate how these skills may be applied to your precision control, guidance or computation systems. Your specific inquiries are invited and will receive prompt replies.

Write for Newest Handbook and Name of Nearest Bowmar Representative

BOWMAR INSTRUMENT CORPORATION

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PRECISION ELECTROMECHANICAL CONTROLS AND INSTRUMENTATION, SERVOMECHANISMS, PRECISION MINIATURE GEARHEADS, NAVIGATIONAL COUNTERS, INDICATING DEVICES

NEW PRODUCTS

DIGITAL DATA SYSTEMS
adapt to existing analog devices

Photos at the right illustrate some of the compatible modular elements recently developed for use in synthesizing a variety of digital data systems. Elements shown include (from top to bottom): a *shaft-position* analog to digital converter adapted for use with a standard GE 4½-in. switchboard instrument; a similar converter designed for use with a Rochester 6-in. bimetallic dial thermometer; a *shaft-velocity* converter directly coupled to an anemometer; and a logic unit designed to accept start, stop, and information pulses from the above converters.

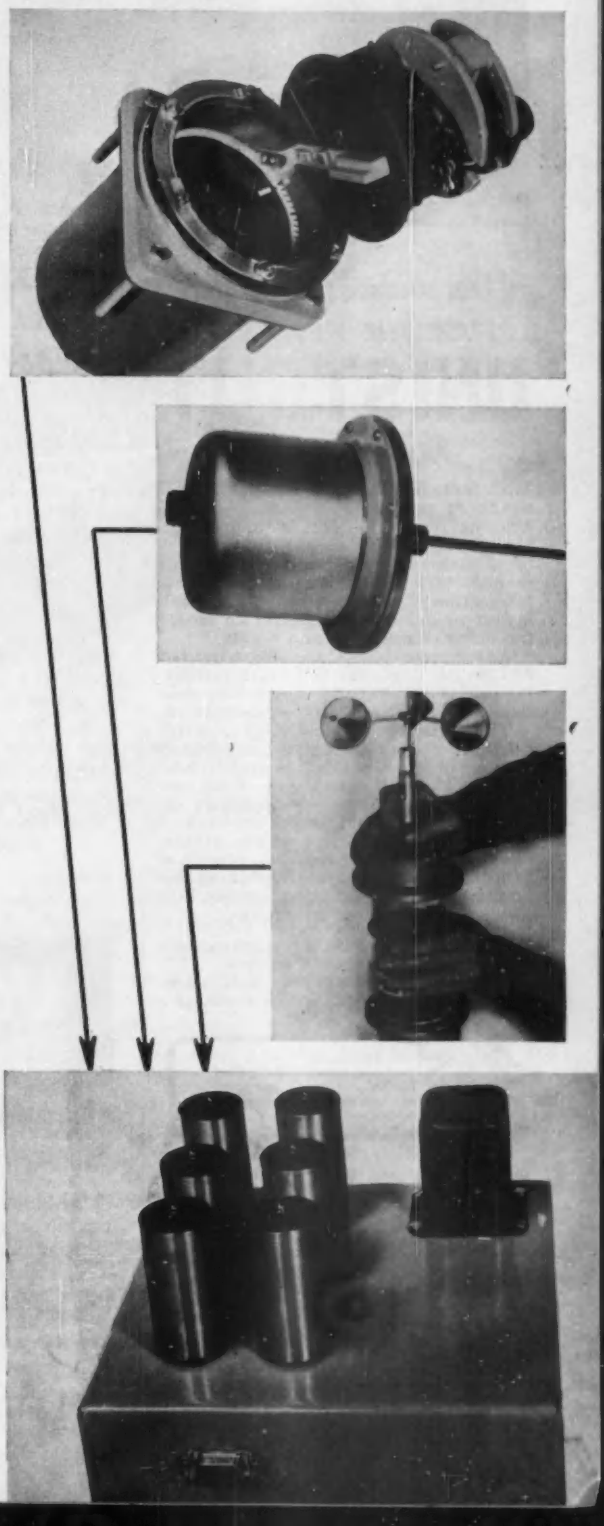
The basic shaft-position transducers are compact dial-reading instruments which mount directly on standard pointer-type instruments. Four signal wires and a common return connect each transducer to the central logic unit. On an "interrogate" command a motor-driven arm sweeps the path of the dial pointer. It carries a lamp and photocell along with contacts that wipe a stationary commutator disc. As the arm passes a zero reference point, a "start counting" pulse goes out. This is followed by a series of information pulses corresponding to dial divisions. When the arm reaches the pointer, a mirror attached to the pointer activates the photocell, sending a "stop counting" pulse to the logic unit.

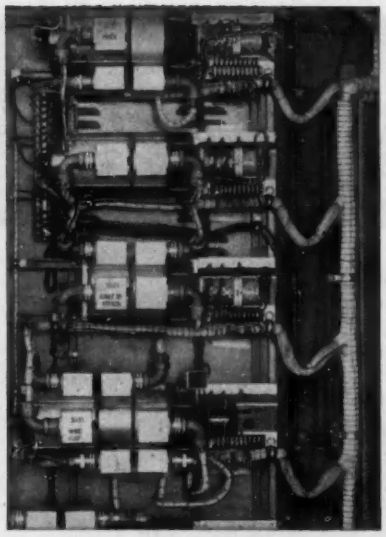
In the shaft-velocity instruments the photocell is fixed and a disc with equally spaced mirror segments is mounted on the rotating shaft. Here the start and stop pulses are spaced by a precisely timed interval, so that the information pulses generated are a true indication of shaft speed.

Another device available but not shown here is a pulse rate converter which consists of a simple amplifier pulse shaper and an accurate time interval generator. This unit is designed to provide output signals equivalent to those of the shaft-position and shaft-velocity transducers that are described above.

The logic unit, heart of any system using these components, receives start pulses, information pulses, and stop pulses from the active converters. A 150-ma, 12-vdc signal passes through an automatic (or manual) selector switch to the converters and sequentially "interrogates" each one. Its operating sequence assures maximum reliability of data. After the "interrogate" signal there is a short delay during which the logic unit ignores any incoming information while the converter's motor comes up to speed. A cascaded decimal counting unit, housed with the logic unit, is gated on when a start pulse is received. It totalizes information pulses until a stop pulse closes the counter gates and produces a "data complete" signal which may be used to initiate a recording cycle, telemetering transmission, or visual readout. Should these events fail to occur within a specified time, a "nonvalid data" signal is generated. This can then be used to block readout of false data.—Advanced Instrument Corp., Richmond, Calif.

Circle No. 309 on reply card





For framing..
for attaching components

...USE THE NEW

UNISTRUT®

FRAMING SYSTEM

With units like the flight simulator cabinet above, achieving compact design and efficient production can be a problem. Use of UNISTRUT metal framing largely eliminated such problems for this manufacturer. There was no costly prefabrication of the framing. No precision layout or drilling was needed to secure the many components and wiring.

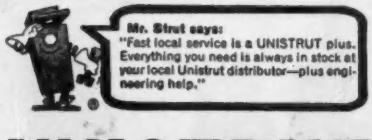
Advantages like these are why the UNISTRUT system is finding increasing use as framing and supports in electronics and instrumentation production.

The patented UNISTRUT spring-held nut which rides in an open slotted channel makes it possible to attach components of any size or shape—from servos to wiring harnesses—anywhere on the channel. Model changes are easy.

UNISTRUT steel and aluminum channel in dozens of sizes . . . plus over 1400 standard fittings are stocked by your local Unistrut distributor. See him or write for complete information.

TO FRAME—panelboards, racks, cabinets, cubicles, stands, 3-dimensional breadboards.

TO SUPPORT—controls, instruments, equipment, harnesses, panels, printed circuit card guides.


Mr. Strut says:
"Fast local service is a UNISTRUT plus. Everything you need is always in stock at your local Unistrut distributor—plus engineering help."

UNISTRUT®

Pioneer in Adjustable Metal Framing

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General Offices: 943 W. Washington Blvd., Dept C, Chicago, Ill.
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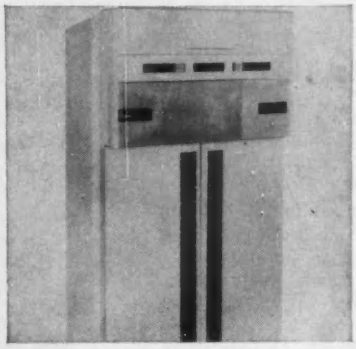
Stocking distributors in all principal cities of the U.S. and Canada. Exported throughout the world.

NEW PRODUCTS

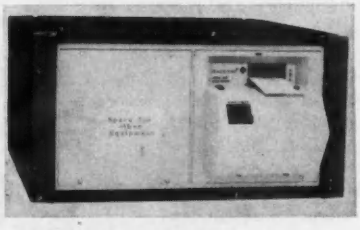
DATA HANDLING & DISPLAY



HANDLES 300,000 A SEC

A newly announced digital tape system is capable of character transfer rates of 300,000 per sec. Total storage greater than 300 million bits is possible on one 6-in. reel of 1-in. wide magnetic tape. A dual-bin tape storage transport design allows unusually low average access times of 20 sec; start and stop times of less than 1½ millisec are possible. A new tape slot guide achieves digital densities of at least 1,000 phase modulation bits per lineal inch. It also holds total skew to a maximum of 3 microsec across 1-in. tape at 150 ips. Speeds to 300 ips are available. The TD 100 system mounts in 72 in. of standard 24-in. rack space.—Shepherd Industries, Inc., Nutley, N. J.

Circle No. 310 on reply card



COMPACT PRINTER

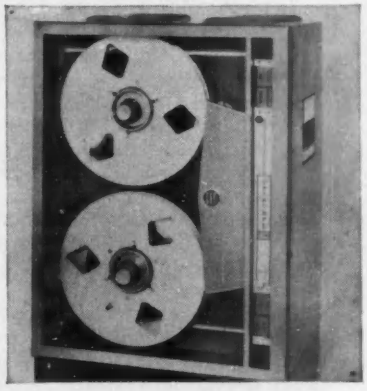
This Model 1453 printer records readings displayed on the manufacturer's counters and prints up to 12 digits at high speeds on paper tape. Printer delays counter only ½ sec to collect data. Two sets of data can be separated by calling for either black or red printout. Standard 1-2-4-8 binary code or the counters' 1-2-2-4 code can actuate the device. Unit occupies only half of an 8¾-in. panel height in a standard 19-in. rack. Basic price: (seven digits): $975, with adapter to hold other equipment in half of 19-in. rack: $1,045; additional digits up to 12 are priced at $50 each.—Beckman Instruments, Berkeley Div., Richmond, Calif.

Circle No. 311 on reply card

BELT PICKS FIGURE

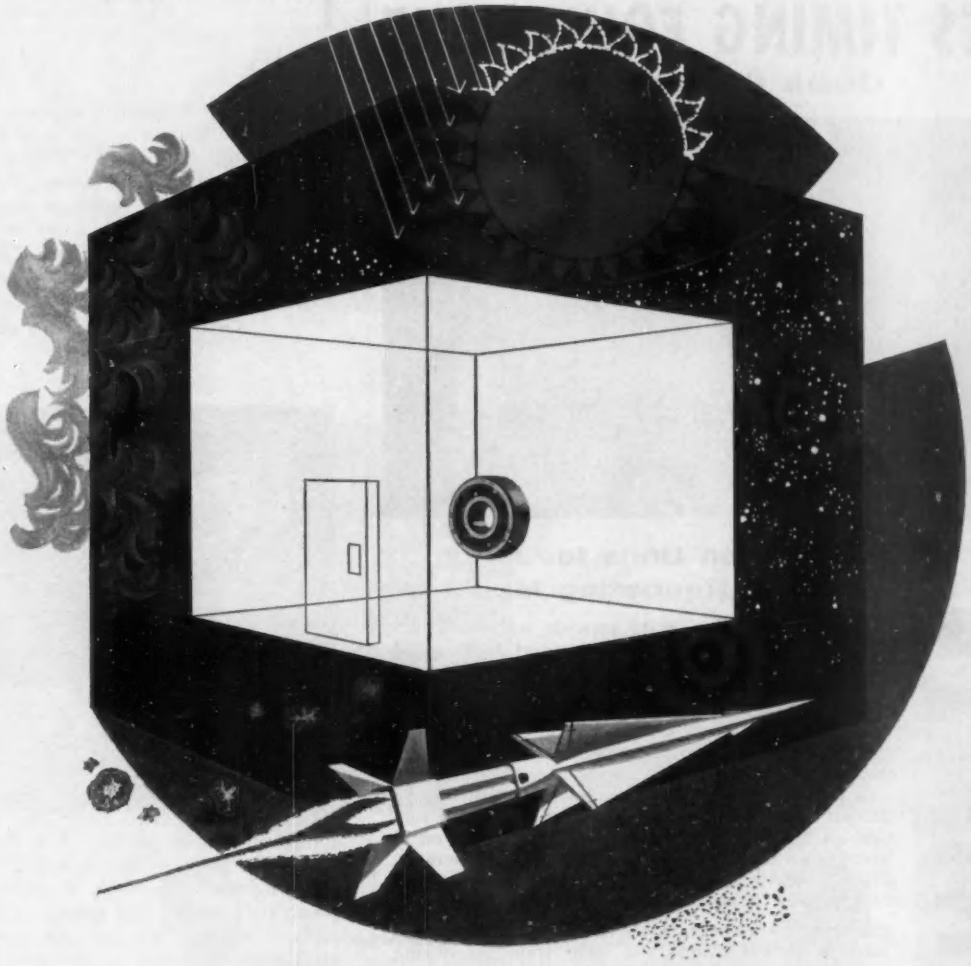
This new indicator uses the position of holes in a moveable message belt to decode input signals. Inputs may be manual or semiautomatic single wire, 4-wire binary, or 10-wire. Belts are translucent Mylar, backlighted by cold cathode lamps, and carry photoprinted digits, letters, symbols, or complete multiword messages. Input initiates drive motor until a preselected series of holes in the belt are positioned under a series of brushes. Positioning is exact. With up to 10 characters on the belt, maximum time of change between most remote characters is 9 sec. Indicator visual areas from ⅜ x 1½ in. to 40 x 4 in. are available.—Electric Indicator Co., Inc., Springdale, Conn.

Circle No. 312 on reply card



PACKS IN FEATURES

This solid state magnetic tape recorder/reproducer has the features of larger instruments in a small package that is easily transported or rack mounted. Only 22¾ in. high by 17¾ in. wide by 15 in. and weighing only 150 lb, the Type PR-2300 is used with a matching case of the same depth and width but 3½ in. high that holds 14 plug-in record or reproduce amplifiers and weighs about 5 lb. Six speeds from 1⅞ to 60 ips are available and are held constant within 0.25 percent. Input range for the direct system is 0.25-25 volts rms for normal



THOR
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TITAN
HAWK
ATLAS
SNARK
NIKE B
BOMARC
NIKE ZEUS
SPARROW I
SPARROW II
SPARROW III
NIKE HERCULES
SIDEWINDER
REGULUS II
VANGUARD
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FALCON

N/D's Unique "White Rooms" Improve Miniature Ball Bearing Reliability!

In these rooms infinitesimal air-borne contaminants are scientifically whisked from the air . . . away from super-precision miniature ball bearing parts. New Departure's White Rooms date back nearly twenty years. And today, they're a major factor in N/D's growing recognition as a leader in M/I ball bearing reliability.

At N/D, miniature ball bearings are completely assembled in properly humidified, temperature controlled atmospheres. Advanced air filter systems completely change the air in these spotless rooms every few minutes. In addition, pressurized access air locks and individual counter-top pressurized chambers are used by N/D's skilled technicians during final assembly and statistical inspections.

These methods and equipment are only a few of the reasons why more and more major missile contractors, today, rely on New Departure Miniature and Instrument ball bearings.

If *you* are working on a new miniature ball bearing application where reliability is critical, include an N/D Sales Engineer in your design discussions. Call or write Department L.S., New Departure Division, General Motors Corporation, Bristol, Connecticut.

DON'T MISS N/D'S EXHIBIT!
BOOTH 207
INSTRUMENT SOCIETY OF AMERICA EXHIBIT

NEW DEPARTURE

MINIATURE & INSTRUMENT BALL BEARINGS

proved reliability you can build around

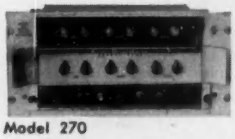
CIRCLE 209 ON READER SERVICE CARD 209

Just set the dials —

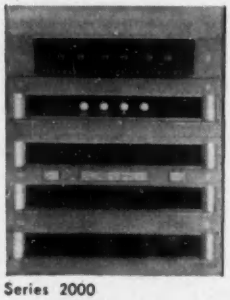
HERMES TIMING EQUIPMENT

does the rest!

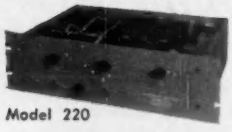
Companion Units for All Types of Recording Media



Model 270

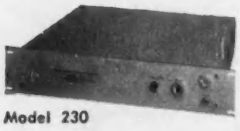


Series 2000



Model 220

Model 225



Model 230

Hermes companion units provide automatic indexing during *data acquisition*, and high speed access to selected data during *data reduction*. Auxiliary equipments provide additional automatic features.

DIGITAL TIMING GENERATOR, MODEL 270, is a solid-state instrument that generates binary coded decimal signals and records them on magnetic tape, providing a precise digital index in terms of elapsed time. Exact time in hours, minutes, and seconds is displayed in illuminated digits. A solid-state Airborne Generator, Model 206A, meeting essential requirements of MIL-E-5400, is also available.

UNIVERSAL MAGNETIC TAPE SEARCH UNIT, SERIES 2000, is used to control a magnetic tape transport during periods of data reduction for automatically searching the tape on the basis of time indices previously recorded. Changing from one time code to another is accomplished by changing time code detectors. All tape times are displayed in decimal regardless of tape time code format.

RETARDED BIT RATE UNIT, MODEL 220, operates in conjunction with Timing Generators, Models 270 or 206A to provide a pulse-height, pulse-width signal for recording time on other than magnetic tape recorders. Operating with Tape Search Unit, Series 2000, it can reproduce previously recorded time on oscillographs.

RUN CODE SELECTOR, MODEL 225, is used with either Model 270 or 206A Timing Generator for inserting data run code numbers, or year, month, and days in between timing words.

TAPE SEARCH PROGRAMMER, MODEL 230, is designed for automatically programming Tape Search Unit, Series 2000, in searching for several sequential start and stop times. The input to Model 230 can be from any digital programming device such as a paper tape reader or computer.

Write for Technical Bulletins on Hermes Timing Equipment

Hermes

ELECTRONICS CO.

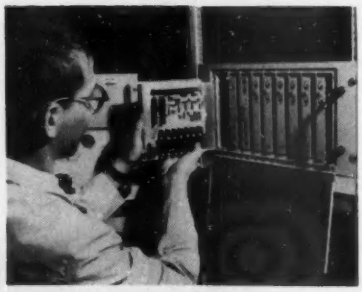
75 CAMBRIDGE PARKWAY, CAMBRIDGE 42, MASS.

A DIVISION OF Itek

WHAT'S NEW

record level; frequency response is 100 cps to 100 kcps ± 3 db at 60 ips. Input range for an FM system is 0.5-50 volts rms for 100 percent modulation. Frequency response ranges from 0-10 kcps ± 0.5 db at 60 ips to 0-312 cps ± 0.5 db at $1\frac{7}{8}$ ips.—Consolidated Electrodynamics Corp., Pasadena, Calif.

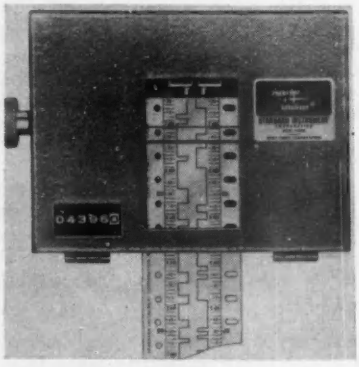
Circle No. 313 on reply card



50 TIMES FASTER

A new analog to digital converter, claimed to be 50 times faster than any similar unit now on the market, is capable of speeds to 2.5 million information samples per sec. Less than 1 cu ft in size, the device is said by its designers to be only a starting point: they predict that speeds of 10 million samples per sec are easily attainable. Accuracy of the present model—$\frac{1}{2}$ percent of full scale—would still be possible.—Raytheon Co., Waltham, Mass.

Circle No. 314 on reply card

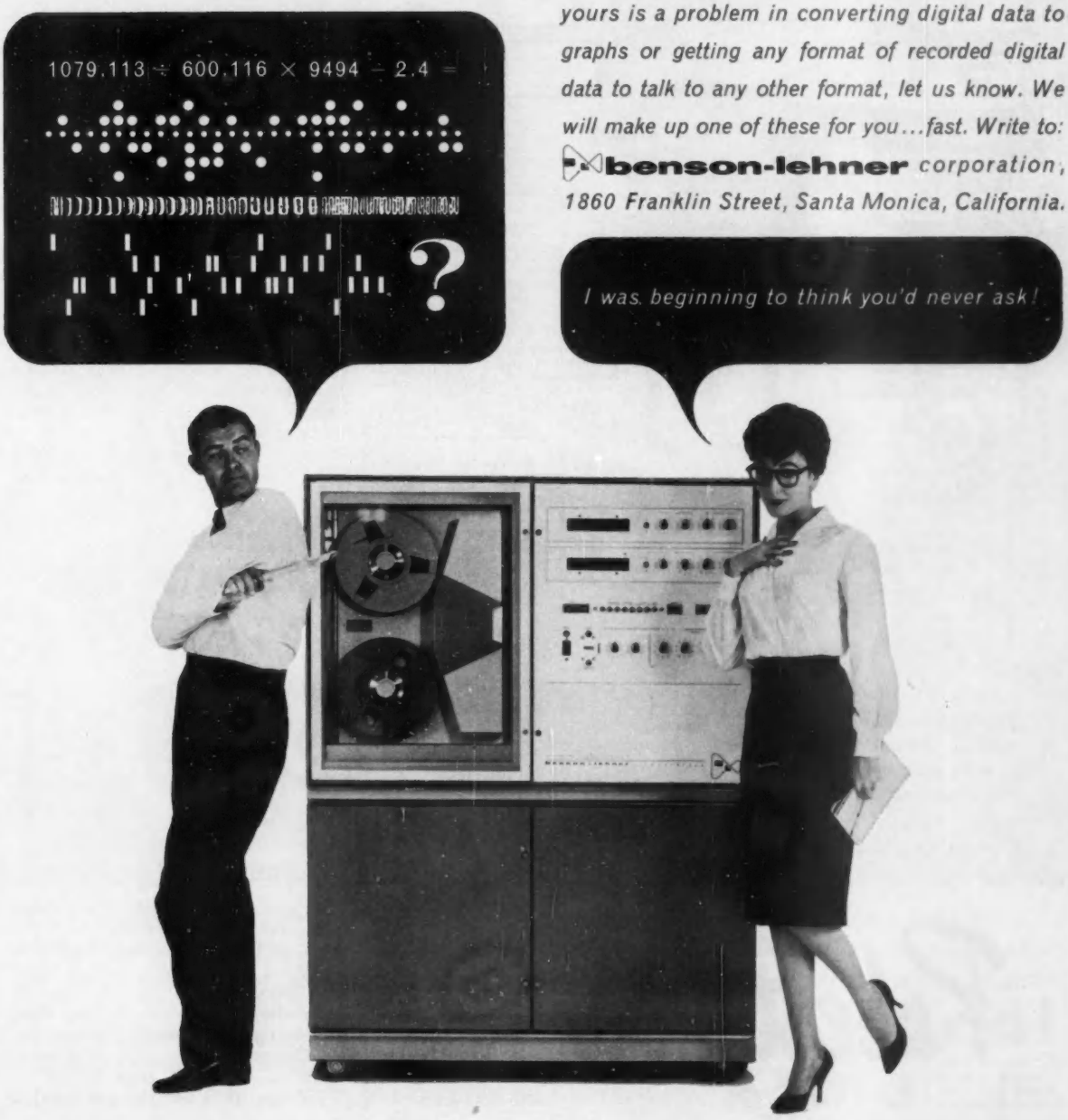


RECORDS PRODUCTION

The two-channel time recorder shown above is designed to record and compare productive time of plant and office equipment. The single strip

Nothing is lost in the translation with Benson-Lehner's new Machine Language Translator. What is gained, however, with this new solid-state instrument is the ability to translate machine languages. The Translator will automatically convert data in one digital code or form to, 1) output in another digital code or form, or 2) to a signal suitable for input into any Benson-Lehner Electroplotter or similar device. Translation speeds are dictated by the input and/or output modes, i.e., operating speed in conversion of digital magnetic tape to graphs is limited by the speed of the graphing instrument. If yours is a problem in converting digital data to graphs or getting any format of recorded digital data to talk to any other format, let us know. We will make up one of these for you...fast. Write to:

benson-lehner *corporation, 1860 Franklin Street, Santa Monica, California.*

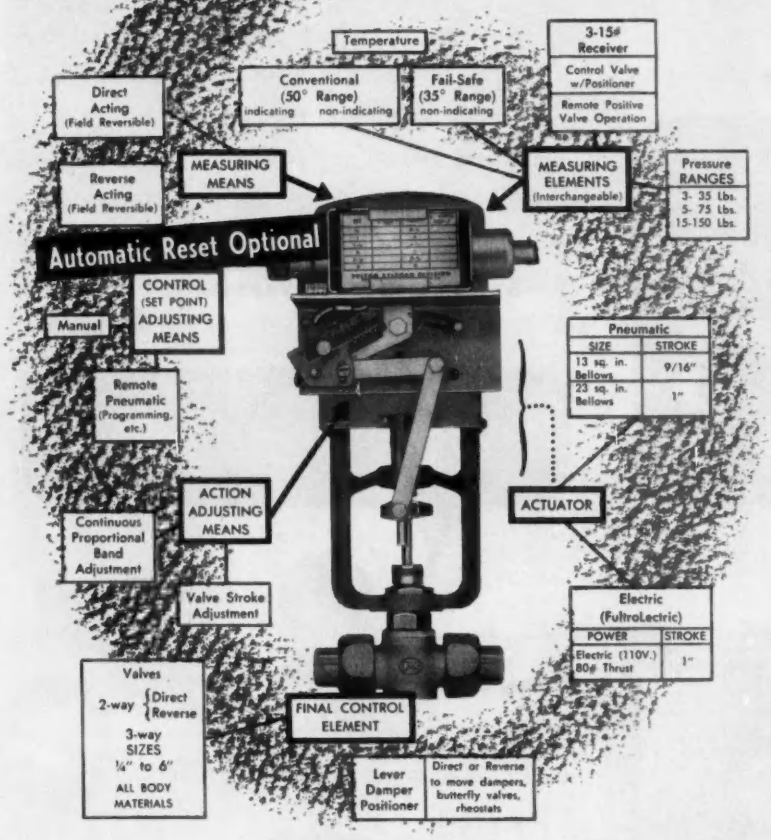


CIRCLE 211 ON READER SERVICE CARD 211

GREATEST FLEXIBILITY IN POWERED CONTROLLERS!

THE NEW FultroMatic® 3-IN-1

Controller·Positioner·Valve



Adding the precision performance of pneumatic control to the ruggedness and simplicity of our famous self-ops, the "one-package" FultroMatic gives positive control for process temperatures or pressures, with wide choice of ranges . . . at about half the cost of 2- and 3-unit systems. For complete data, write today for Bulletin GW-755. **Fulton Sylphon Division, Robertshaw-Fulton Controls Co., Knoxville 1, Tennessee.**

Robertshaw® MR. CONTROLS

212 CIRCLE 212 ON READER SERVICE CARD

NEW PRODUCTS

chart carries space for the graph of the operating patterns of two machines, two functions of one machine, or any two processes. A distinction may be made between productive time and idling time. A totalizer furnishes continuous sum of productive time in hours and tenths or minutes and tenths. Chart speeds are 1, 4, 12, or 60 in. per hr. Slower charts are available to run four months without change. Price: $95.–Standard Instrument Corp., New York, N. Y.

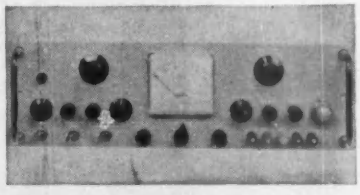
Circle No. 315 on reply card

PLUS . . .

(316) A new series of transistorized **counters** employing digital logic techniques to register inputs at rates to 100 kc is available from **Datex Corp.**, Monrovia, Calif. . . . (317) **Keinath Instrument Co.**, Columbus, Ohio, has introduced a new type of **multiple recorder and annunciator** that displays on one chart all the variables in the most complex process. . . . (318) A photoelectric **block-reading tape reader** that stresses minimum maintenance and can read up to 80 bits simultaneously at speeds to 6 blocks per sec has been announced by **Photocircuits Corp.**, Glen Cove, N. Y.

Circle Nos. 316, 317, 318 on reply card

RESEARCH, TEST & DEVELOPMENT



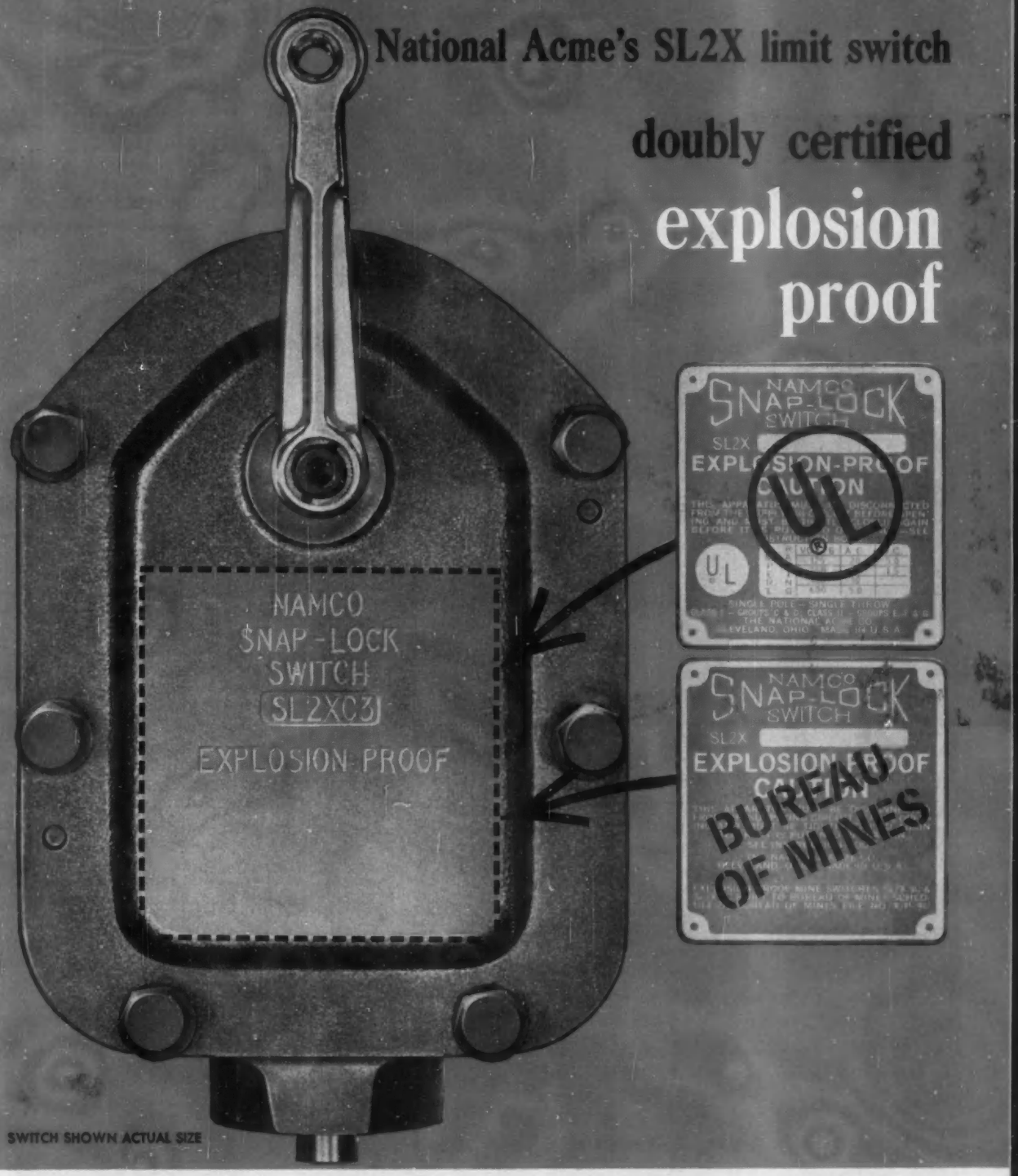
TELEMETRY CALIBRATION

The new Model 202 signal simulator simulates a precise PAM or PDM serial pulse train, and the Model 203 simulates PAM-NRZ as well as PAM and PDM for use in calibration of telemetry ground stations and data processing equipment. Besides the IRIG standard pulse rates, these units offer an extended range of 20 to 7,200 pps. Both negative and positive

National Acme's SL2X limit switch

doubly certified

explosion proof



SWITCH SHOWN ACTUAL SIZE

Specify National Acme's SL2X . . . and eliminate limit switching problems under explosive conditions. Tested and certified "explosion-proof" by both Underwriters' Laboratories and the Bureau of Mines, the SL2X is specifically designed for use in the mining, chemical, process industries . . . anywhere explosions cannot be tolerated. Latest of National Acme's dependable SL2 "Machine Life" Limit Switches, the SL2X also offers . . . a variety of cam arrangements for extreme operating flexibility . . . ample overtravel (67°) and by-pass (90°) . . . light operating pressure (12½ lbs. at 1½" radius). Get all the details on this new standard of limit switching dependability and safety. Call, write or wire.

National Acme

THE NATIONAL ACME COMPANY
165 E. 131st STREET
CLEVELAND 8, OHIO

Sales Offices: Newark 2, N. J., Chicago 6, Ill., Detroit 27, Mich.

CIRCLE 213 ON READER SERVICE CARD

this is *Micro Mod*

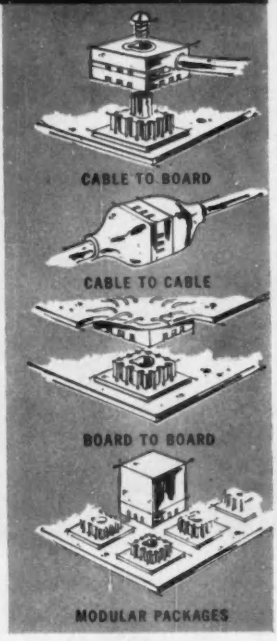
A pair weighs 0.73 grams; they are .380 square; there are 12 gold-plated beryllium copper contacts on .075 centers: this is Micro Mod, AMPHENOL's new connector family for modular circuitries!

Available in two constructions, Micro Mod can be used with module ("or stick") circuits or in cable plug applications—wherever micro-miniaturization must be combined with outstanding reliability.

96-4 plug is used with 96-3 receptacle; the latter is supplied less contacts—the module leads are used to form the female contacts. 96-2 plug is supplied with a polarizing key assembly, mates with 96-1 receptacle.

Small quantities of Micro Mod connectors can now be ordered for evaluation.

Cataloging is available for your use.



AMPHENOL CONNECTOR DIVISION

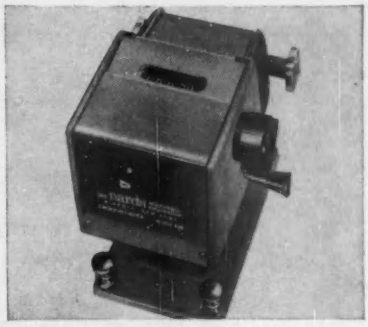
1830 South 54th Avenue, Chicago 50, Illinois
Amphenol-Borg Electronics Corporation

CIRCLE 214 ON READER SERVICE CARD

NEW PRODUCTS

output signals are available. Linearity and stability are within 0.20 percent; noise and crosstalk are within 0.1 percent. Both models are 5.25 in. high and fit a standard 19-in. rack.—Telemetrics, Inc., Gardena, Calif.

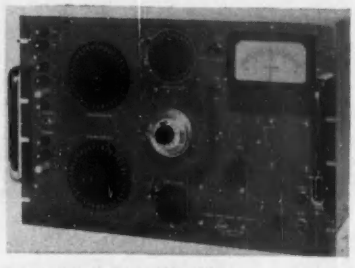
Circle No. 319 on reply card



DIGITAL READING

Claimed to be the only microwave frequency meter that indicates frequency directly on a digital counter, the new device shown above features ease of rapid, precise reading. High-Q cavities are precision bored and coupled to the narrow wall of a section of the waveguide. The unit is designed so that it is electrically equivalent to a straight section of waveguide when detuned (VSWR = 1.05 except at resonance). At resonance a small amount of power is reflected, and there is at least a 10 percent dip—over the frequency range—in the transmitted power. Three models for the X, KU, and K bands are priced at $195, $250, and $275, respectively.—Narda Microwave Corp., Mineola, N. Y.

Circle No. 320 on reply card



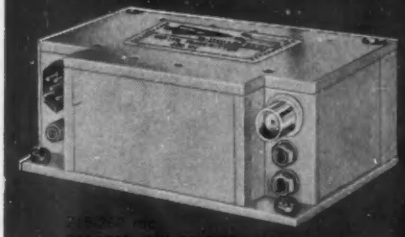
ACCURACY TESTER

This new system error bridge is a device designed to test the steady state accuracy of flight control systems that receive their input from synchros or resolvers. The rack mounted in-

TELE CHROME

HIGH POWER
IN SMALL PACKAGES

NEW



1463 Series — Transmitter

5 19/32" x 3 1/16" x 4"
15 to 30 Watts

Model 1460-M RF Amplifier

3.37" x 3.25" x 2"
2 Watt input; 10-30 Watt output

Heat sink cooling

THE MOST COMPLETE LINE

1466 Series — RF Amplifier

6.5" x 4" x 3.25" RF Amplifier
2 watts in — 100 watts out

1462 Series — Transmitter

6" x 4¼" x 3¾"
50 to 80 Watts

800C—Sub Carrier Oscillator

1.5" x 1.9" x 2.45"
Dev. Stab: ± 1% band width
Dev. Linearity: Less than 1% band width

TELE CHROME

CIRCLE 215 ON READER SERVICE CARD

New Panel Meters by DeJUR

Offer Improved Reliability and Readability

Now, DeJur has designed high precision and complete reliability into a standard, off-the-shelf panel meter for original equipment and replacement applications. A wide arc scale plate combined with the modern, streamlined case provide improved readability and attractive appearance. These internal core magnet units develop greater torque and are self-shielding. Model 25 instruments are available as DC and AC Microammeters, Milliammeters, Ammeters and Voltmeters . . . **these units soon available through your distributor.**

SPECIFICATIONS

ACCURACY ..... ±2% of Full Scale	TERMINALS . . Threaded stud type, #8-32
CALIBRATION ..... Mounts on Panel of Any Material	MOUNTING HARDWARE ..... Three 4-40 nuts and three #4 lockwashers supplied
SCALE ..... 2½" Long	CASE ..... Plastic, not sealed
ZERO ADJUSTER ..... External	MOUNTING DIMENSIONS ... 3-Hole per ASA—C39.1
POINTER ..... Lance (other shapes on order)	EXTERNAL MAGNETIC EFFECT ..... NIL

Write for detailed literature on complete lines

You're always sure with

DeJUR

ELECTRONIC COMPONENTS

ELECTRONICS DIVISION
DeJUR-AMSCO CORPORATION
45-01 NORTHERN BOULEVARD
LONG ISLAND CITY, N. Y.

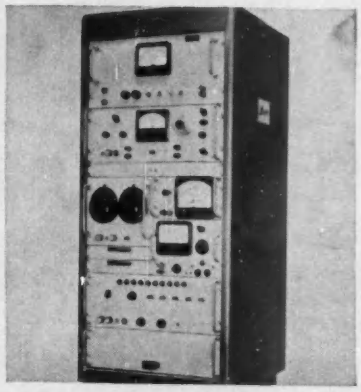
Manufacturers of Precision Electronic Components for Over 35 Years

trument allows angular inputs to be dialed into the autopilots. For the test the unit replaces the vertical gyroscope and magnetic compass.

Characteristics:

Range: 0-360 deg continuous
Resolution: 4 sec of arc
Absolute accuracy: 20 sec of arc
Size: 19 in. wide by 10½ in. high by 8 in.
—Theta Instrument Corp., Saddle Brook, N. J.

Circle No. 321 on reply card



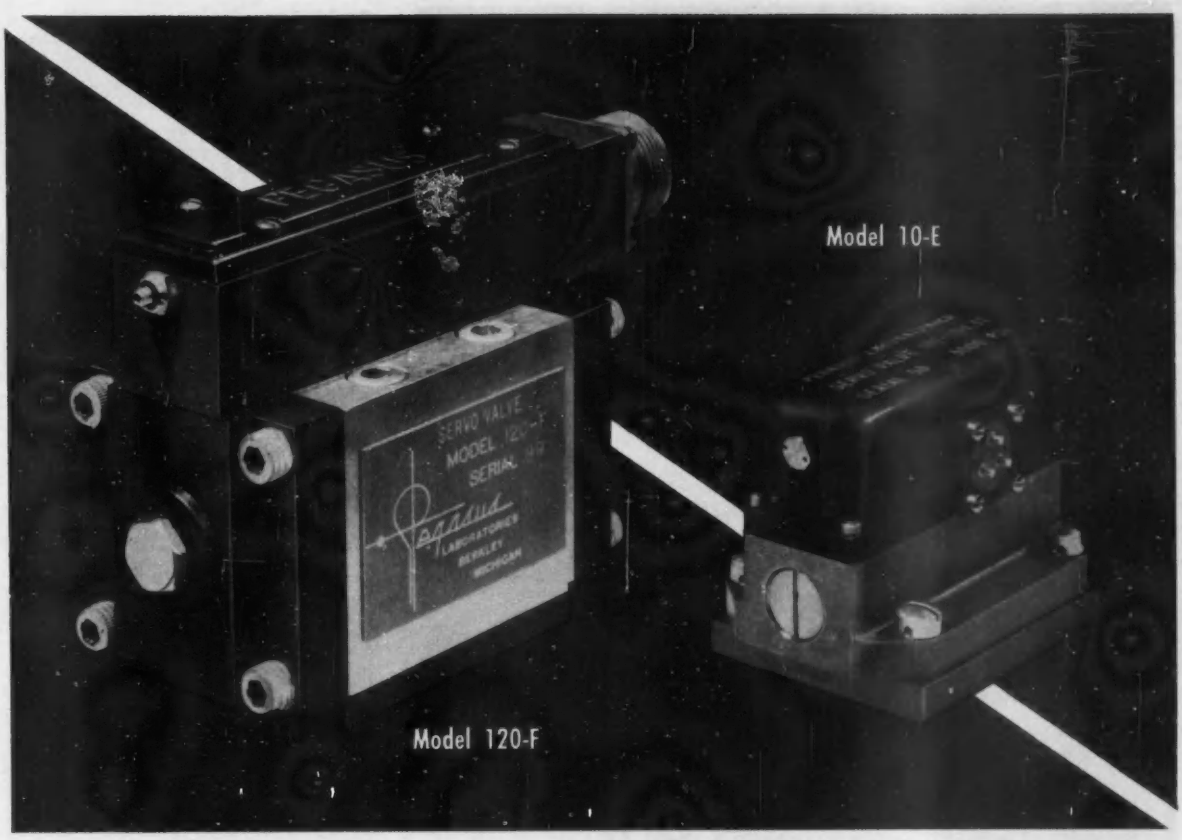
TESTS SYNCHROS, RESOLVERS

The console pictured above is a highly accurate, semiautomatic unit for testing 400-cycle resolvers, syncro transmitters, differentials, and control transformers. It consists of a phase sensitive voltmeter, filtered vtvm; and relay, transformation ratio, and power supply modules. Accuracies of test regimes are: input voltage, 2 percent; input current, 2 percent ±1 ma; rms and fundamental nulls, 2 percent ±2 mv; transformation ratio, 0.2 percent; composite error from EZ, ±30 sec. Size of unit is 50⅞ x 21⅞ x 22 in.—Kearfott Div., General Precision, Inc., Little Falls, N. J.

Circle No. 322 on reply card

SPEEDY PULSE GENERATOR

Designed for use in design and test of high speed pulse circuitry, the new Model 4550A pulse generator is capable of 10-Mc pulses. A double pulse version, the 4565A, is also available. Although intended primarily for the megacycle region, the units perform well also in the low and medium ranges as general purpose test instruments. Repetition rate is variable



PEGASUS for the Finest in Industrial and Aircraft Servo Valves

Pegasus Industrial and Aircraft Servo Valves utilize a powerful force motor and frictionless spool boost system which requires very low input power yet provides extremely high valve spool drive stiffness.

This high spool drive stiffness, as well as the completely symmetrical design, insures fine sensitivity without dither and low null shifts over large ranges of operating pressure and temperature.

Only 10 micron filtration is required for long, reliable performance.

Pegasus valves are now being shipped with complete electrically recorded data on the flow gain, linearity, hysteresis, leakage, pressure gain and sensitivity, to lower your receiving inspection costs.

PEGASUS LABORATORIES, INC.

DESIGNERS AND MANUFACTURERS OF ELECTRO-HYDRAULIC SERVOMECHANISMS

3690 W. ELEVEN MILE ROAD • BERKLEY, MICHIGAN

CIRCLE 217 ON READER SERVICE CARD 217

REC's.....

Precision Temperature Probes.....at off the shelf prices!

Want low cost temperature probes on short notice – without sacrifice in quality? Rosemount Engineering Company now offers high-performance platinum resistance temperature sensors from stock.

MODEL 179A
Sensing element fully supported, mounted in ceramic insulation. Stainless steel guard tube with additional support at the element tip gives maximum protection from flow.

MODEL 179A

MODEL 152T

MODEL 152T
Sensing element supported by a light cage and exposed to working fluid to give extremely fast response in fluids which are not electrical conductors. Element protected by stainless steel guard tube with additional support at the element tip.

Fourteen stem lengths and 6 different fittings of each model available. These immersion probes have wide application in research, development and industrial process controls. Recommended for use in most hydrocarbons, gaseous or liquid air, oxygen, nitrogen, hydrogen or helium. Sensing elements, of precision platinum, are calibrated at liquid helium point and the ice point. General specifications:

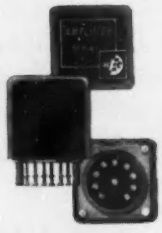
- Temperature Range – from –435°F to 500°F
- Stability – Stable within 0.20°F at 32°F
- Pressure – 6,000 psi maximum
- Element Length – from 1⅛" to 2¾", in ⅛" increments
- Time Constant – 152T – 0.2 seconds } Dow Corning No. 200
  179A – 0.5 seconds } 1.5 CTSK Oil
- Resistance at 32°F – 152T – 200 ohms
  179A – 500 ohms

For additional information write for advance bulletin number 5603.

Plus Circuit Modules

Rosemount also offers a series of preassembled circuit components, featuring small size and durability. Built to meet environmental requirements of MIL-E-5272 and MIL-E-8189.

- General purpose amplifier, Model 510A, 40 db voltage gain minimum, 10 cps to 100,000 cps, –55°C to 125°C.
- High impedance input amplifier, Model 511A, 20 db power gain, input impedance greater than 1 x 10^6 ohms, 10 cps to 50,000 cps, –55°C to 125°C.
- Power supply, Model 531A, 117 volts, 400 cps; 20 volt DC regulated, 10 milliamperes, 0.1 percent ripple, –55°C to 125°C.
- Rectifier-filter, Model 532A, diodes and RC filter for two full wave DC supplies. Rated 30 volts DC each at 0.1 percent ripple, –55°C to 125°C.



(Size 1 x 1 x 1 Inch)

For additional information write for advance bulletin 46028.

ROSEMOUNT ENGINEERING COMPANY

4900 West 78th Street, Minneapolis 24, Minn.

NEW PRODUCTS

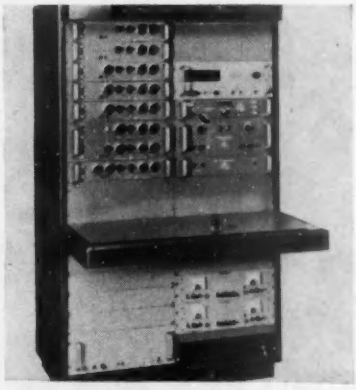
10 mcps to 100 cps; delay is variable 0.02 to 1,000 microsec; duration is variable 0.05 to 1,000 microsec; rise time is less than 10 millimicrosec; and output amplitude is 12 volts open circuit, 8 volts into 180-ohm load.–Electro-Pulse, Inc., Culver City, Calif.

Circle No. 323 on reply card

DETECTS DEFECTIVE TAPE

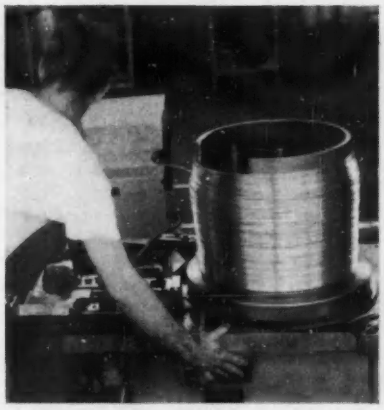
Able to detect tape defects as small as one bit length at speeds to 150 ips and packing densities as high as 1,500 bits per in., the Model 3320 magnetic tape tester is composed of standard components plus a tester logic unit. A pilot lamp lights to indicate defect and the transport stops on the fault, which is easily accessible for inspection and repair.–Potter Instrument Co., Inc., Plainview, N. Y.

Circle No. 324 on reply card

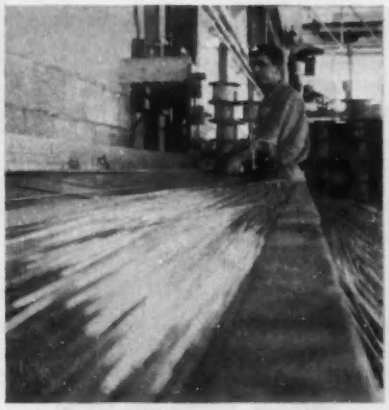


AUTOMATIC TESTER

Completely automatic, high speed testing of transistors and diodes in production and incoming inspection is possible with this newly announced



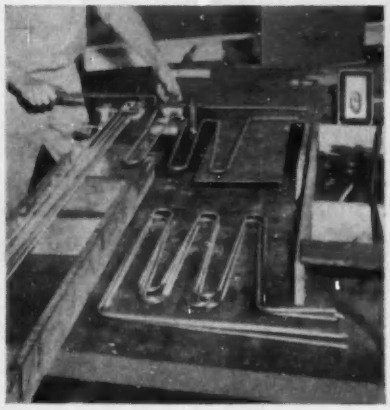
PLUG DRAWING



STRAIGHTENING

DEBURRING

CLEANING



FORMING

FLOW TESTING

PACKAGING

METICULOUS . . .

. . . is the way Webster would define Kensico's "*commendable extreme carefulness*" in producing small diameter copper tube for use in both instrumentation and control systems. At every step in production, Kensico technicians exercise the utmost care to insure that each order processed by our newly expanded Small Tube Dept. is painstakingly filled to customer's exact specifications. Kensico draws Restrictor and Capillary Tube to .026″ inside diameter, cut to exact straight lengths, plastic capped and bundled—or coiled on a reel up to 10,000 feet. Free Flow Charts and engineering consultation available upon request. Write today!

Kensico Tube
COMPANY DIVISION
Robinson Technical Products, Inc.
MOUNT KISCO, NEW YORK

Kensico Products are also available through Warehouse Distributors and Sales Representatives in Cambridge, Mass.; Middlebury, Conn.; Buffalo, N. Y.; Lindenhurst, N. Y.; Goshen, N. Y.; Roselle, N. J.; Philadelphia, Pa.; Flourtown, Pa.; Pittsburgh, Pa.; Cleveland, Ohio; Detroit, Mich.; Chicago, Ill.; Evanston, Ill.; St. Louis, Mo.; Milwaukee, Wisc.; Durham, N. C.; Ft. Lauderdale, Fla.; St. Petersburg, Fla.; Dallas, Texas.

CIRCLE 219 ON READER SERVICE CARD 219

Another new Westinghouse AIR CIRCUITRY Component

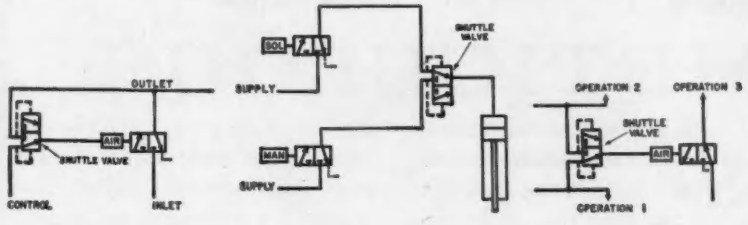
SHUTTLE VALVE

The Westinghouse Shuttle Valve automatically selects and directs the flow of air from one or the other of two controlling devices to a common outlet. It serves to connect two independent lines to a common line without destroying the segregation. A few of its uses are shown below.

Simple—Lightweight—Sensitive It contains only **one** moving part—an easily replaceable rubber diaphragm. Two body segments, a gasket and four screws complete the assembly. It has no springs. Nothing can bind or stick. Its compact size presents no installation problem.

Weighing only **6 ounces,** it can easily be supported by piping alone. Mounting feet are included, however, for installation with vibration or long pipe runs. It is so sensitive that it will seal off the opposite inlet line with less than 1 psi pressure differential.

TYPICAL APPLICATIONS



LOCK-UP
Insures an operation is held constant once initiated. Outlet line must be vented by another means to unlock the system. ("Memory" Circuit)

TWO-STATION CONTROL
Either of two controlling devices may operate the cylinders. Inoperative controlling device is sealed from the line. ("Or" circuit)

INTERLOCK
Prevents operation #3 when operation #1 or #2 is in process. ("Not" circuit)

AIR CIRCUITRY means trouble-free automation

Air Circuitry is the application of pneumatic control systems to industrial production operations.

Air circuits are safe, economical and precise and are used to solve the most rigorous and complex control problems in industry.

Our engineers, backed by 90 years of experience, can help you boost production and cut costs in your plant.

For more information, ask for Data Sheet A6-104-02

See the Yellow Pages under Cylinders for the Name of Your Local Distributor, or refer to Sweet's Catalog, Product Design File.

WESTINGHOUSE AIR BRAKE COMPANY
INDUSTRIAL PRODUCTS DIVISION, WILMERDING, PENNSYLVANIA

220 CIRCLE 220 ON READER SERVICE CARD

test station. Evaluation of performance is accomplished by means of a precision go/no-go comparator. Testing rate is 700 semiconductors an hour with 100 percent measurement reliability. Over 100 measurements can be made; 25 tests can be included in one sequence. Power ratings are 0-100 volts and up to 3 amp. Test accuracy is 1 percent. Price: approximately $10,000, depending on selection of modules.—Optimized Devices, Inc., Thornwood, N. Y.

Circle No. 325 on reply card

PRIMARY ELEMENTS & TRANSDUCERS

LOW DRIFT

The new Zero One series of high precision miniature floated gyros features trimmed drift rate of less than 0.1 deg per hr. These units have an angular momentum of 300,000 cgs units and a mass unbalance of less than 0.4 deg per hr per g. Diameter of the case is 1.8 in., and the gyro's total weight is approximately ½ lb.—Reeves Instrument Corp., Garden City, N. Y.

Circle No. 326 on reply card

DETECTS 5 MICROIN. MOTION

A new linear potentiometer responds to motion as small as 5 microin. De-

WHERE DO YOU STAND ON COMPUTER CONTROL— LEADING OR LAGGING?

Far-sighted leaders in industry are realizing the benefits made possible by applying computer control systems to their processes.

Working with these leaders, General Electric has already pioneered the application of twenty on-line GE-312 computer systems now being implemented in these basic areas —STEEL, ELECTRIC UTILITIES, CHEMICAL, CEMENT, and PRODUCTION CONTROL for various manufacturing applications.

The GE-312 Computer Control System embodies adaptability and flexibility to meet many types of applications in varying size plants. For example, compare its expansible memory—capacity up to 52,000 words. Compare its flexible input/output—capable of scanning up to 1500 instrument inputs. These are maximum capabilities, expansible from a minimum system. You buy a system tailored to your exact requirements.

Add to this versatile equipment the computer systems engineering ability demonstrated by General Electric in implementing these twenty GE-312 system applications.

Add also the long history of General Electric overall systems know-how—its broad background in the equipment, processes and materials to which you apply computer control.

Tomorrow's profits will come from today's combination of vision, equipment, and know-how. *Where do you stand?*

There are General Electric Sales and Application engineers in over one hundred offices throughout the nation to serve you. *Phone* the nearest General Electric Apparatus Sales Office, or *wire* General Electric Computer Department, 13438 North Black Canyon Highway, Phoenix, Arizona.

PROCESS CONTROL
AUTOMATED BY GENERAL ELECTRIC

Progress Is Our Most Important Product

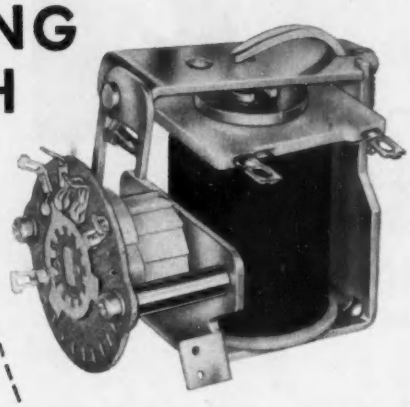
GENERAL ELECTRIC

CPA-50 (9-60)

General Electric—a pioneer in computer systems for all phases of business, industrial, scientific, engineering, and financial endeavor.

NEW

STEPPING SWITCH



COMAR
TYPE ACS

- Economical
- Compact Size
- Easily Mounted

Designed for sequence controlling, counting, totalizing, scanning and information storage. Modifications available for a variety of switching applications.

SPECIFICATIONS: Operating voltage up to 230 V.A.C.; Voltage range, −15% to +10% of rated voltage; Operating speed, 300 ppm.; Nominal power, 20 volt-amperes A.C. minimum; Contact combinations available. 2, 3, 4, 8 or 12 single pole continuous rotation, for shorting or non-shorting steps; Rating, 1 ampere at 115 V.A.C.; Insulation tested at 1000 V.R.M.S.; Impregnation to specifications.

Send for complete details!

Comar Electric

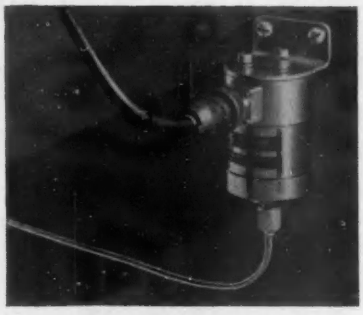
3349 ADDISON ST., CHICAGO 18, ILLINOIS

RELAYS • SOLENOIDS • COILS • SWITCHES • HERMETIC SEALING

222 CIRCLE 222 ON READER SERVICE CARD

signed for ac or dc input, the device provides outputs to 350 volts per in. of displacement without amplification. Life rating of 30 million strokes is claimed. Resistance range is 250 ohms to 125 kilohms per in. of stroke; linearity is within 0.2 percent of length of stroke. Stroke lengths are from ¼ to 10 in.—Computer Instruments Corp., Hempstead, N. Y.

Circle No. 327 on reply card



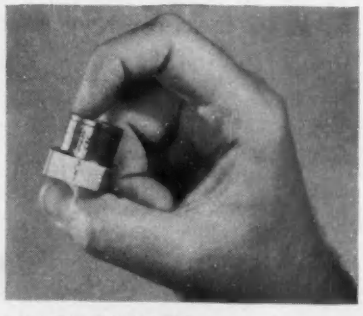
FOR ABSOLUTE PRESSURE

Designed for accurate measurement of absolute pressure over a wide temperature range, this new transducer features cavity cleanout, infinite resolution, and standard built-in pressure overload protection.

Characteristics:

Repeatability: within 0.1 percent
Linearity: within 0.25 percent
Hysteresis: 0.25 percent
Ambient temperature range: −100 to +275 deg F
Pressure ranges: 0-300 and 0-2,000 psi
—Taber Instrument Corp., North Tonawanda, N. Y.

Circle No. 328 on reply card



NONE SMALLER

Said to be the smallest temperature compensated strain gage accelerom-

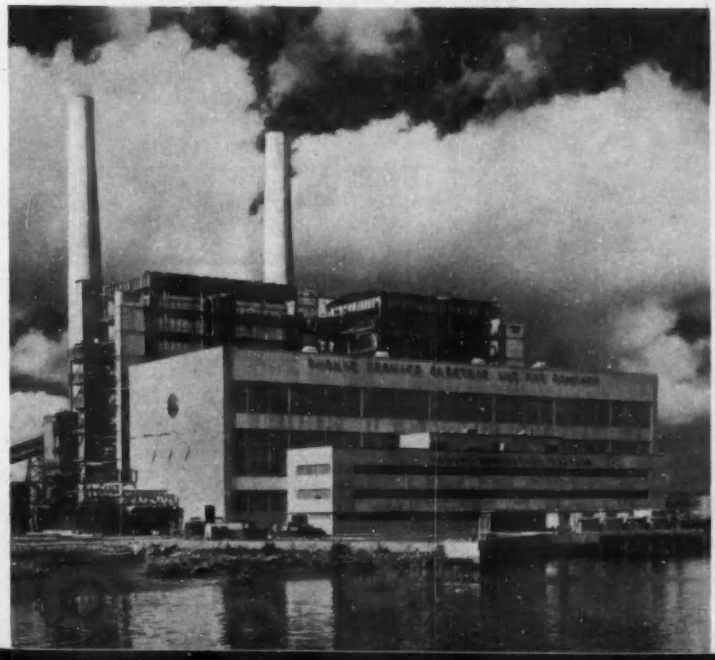
ANOTHER BREAKTHROUGH IN PRODUCT DESIGN MADE POSSIBLE BY PHILCO TRANSISTORS

SMALL WONDER

THIS TINY PHILCO TRANSISTOR is the famous MADT® (Micro Alloy Diffused-base Transistor), developed and manufactured by Philco. It is used extensively in computers for switching electric current at tremendous speeds.

IN THIS NEW LN 3000 COMPUTER . . . developed by Philco under joint agreement with Leeds & Northrup Company . . . over 1200 MADT Transistors are used. LN 3000 Computers are sold by Leeds & Northrup as part of their complete control systems and are among the most compact and reliable process computers available.

FOR AUTOMATIC PROCESS CONTROL this new computer is applicable in many industries . . . including electric power, metals, chemicals, petro chemicals and ceramics. The first LN 3000 will soon be installed in this modern control center to calculate the performance of the generating units.



IN THIS GIANT POWER PLANT . . . the Bergen Generating Station of the Public Service Electric and Gas Company, at Ridgefield, N.J. . . . the LN 3000 will calculate equipment performance and aid in more efficient production of electricity for one of the nation's busiest industrial areas.

This is another major electronic achievement made possible by Philco Transistors. Specify Philco Transistors in all electronic equipment you buy . . . or build. Consult Philco for information or assistance in transistorizing your product.

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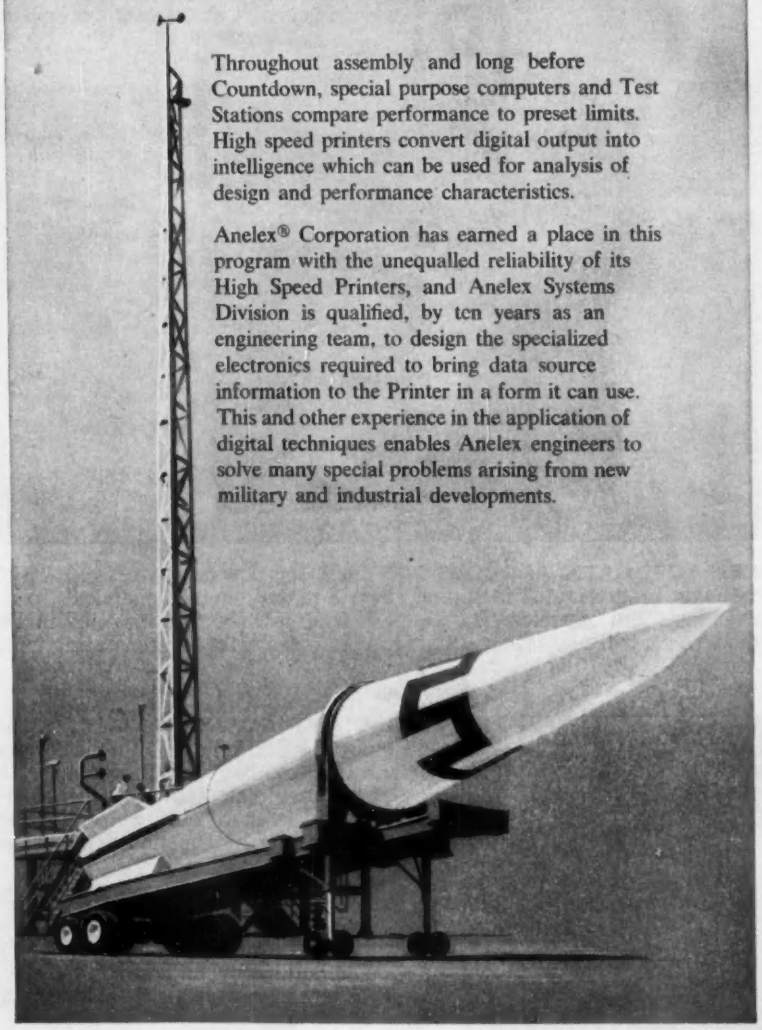
Long Before Countdown...

Throughout assembly and long before Countdown, special purpose computers and Test Stations compare performance to preset limits. High speed printers convert digital output into intelligence which can be used for analysis of design and performance characteristics.

Anelex® Corporation has earned a place in this program with the unequalled reliability of its High Speed Printers, and Anelex Systems Division is qualified, by ten years as an engineering team, to design the specialized electronics required to bring data source information to the Printer in a form it can use. This and other experience in the application of digital techniques enables Anelex engineers to solve many special problems arising from new military and industrial developments.



for further information, write or telephone

ANELEX

ANELEX CORPORATION

150-D CAUSEWAY ST., BOSTON 14, MASS.

NEW PRODUCTS

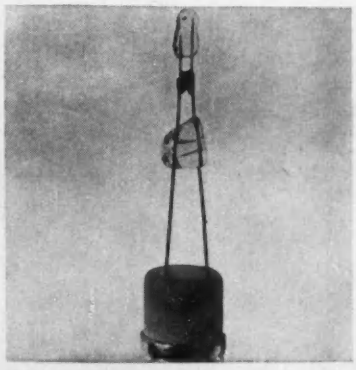
eter available, the Type 4-202 is a linear, unbonded, bidirectional device. It is designed for measuring accelerations perpendicular to the mounting surface. The accelerometer weighs only 3 oz and occupies just 1 cu in. Its linearity and hysteresis qualities are conservatively rated to within less than ±0.75 percent of full range output. A nonpendulous-type mass suspension allows a low cross-axis sensitivity of less than 0.01 g/g for an input three times rated range. Standard ranges are from ±5 to ±500 g. Input voltage is 5 volts with full range output of 40 mv (±20 mv).—Transducer Div., Consolidated Electrodynamics Corp., Subsidiary of Bell & Howell Co., Pasadena, Calif.

Circle No. 329 on reply card

ACCURATE DETECTOR

Temperatures as high as 1,500 deg F may be measured with greater accuracy and stability than possible before using a new detector now available. This resistance device is hermetically sealed in its own well for use under pressures up to 300 psi and fits standard ⅜-in. bore thermowells.—Instrument Div., Thomas A. Edison Industries, McGraw-Edison Co., W. Orange, N. J.

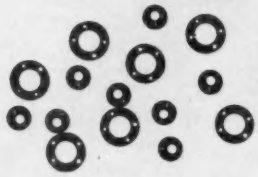
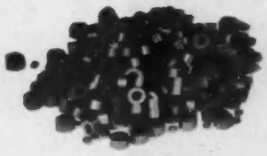
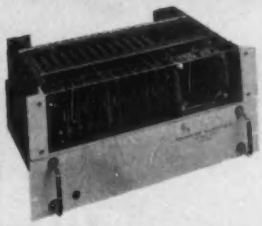
Circle No. 330 on reply card

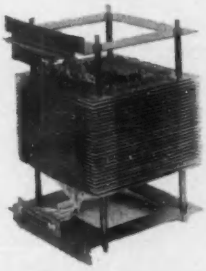
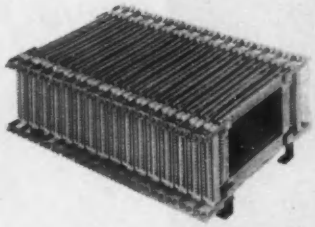
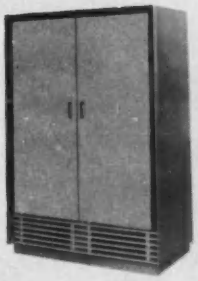
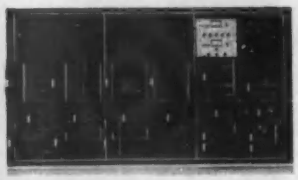


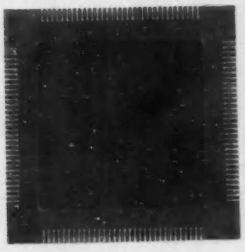
SUBMINIATURES

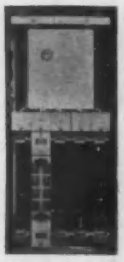
Humistor is the name given to a subminiature device for detecting and measuring vapor and gases which exhibit an electric dipole moment. Minute vapor concentrations are detectable; classification of mixtures is possible through use of selectively transparent coatings. Output of the humistor is a change in resistance

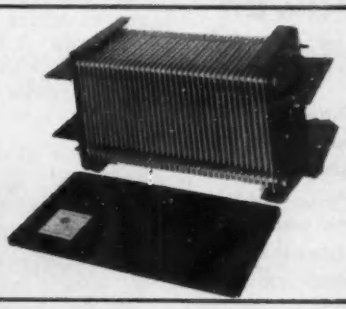
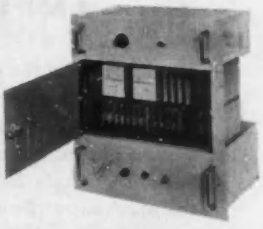
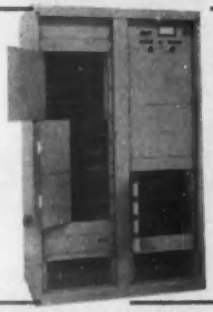
TMI, THE LARGEST MANUFACTURER OF MEMORY PRODUCTS •

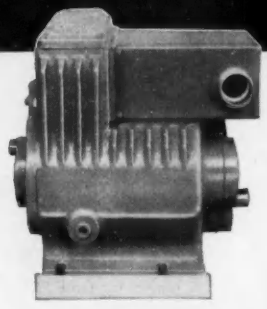









Since our engineers delivered the first commercial core memory in 1954, TMI has carefully created and built an integrated design, development, and manufacturing organization producing the only complete line of ferrite core memory products available. TMI sales engineers, conveniently located in field sales offices throughout the country, are anxious to help you with your digital storage problems, whether for 500 cores or 5 million cores, for a 500 bit buffer, or a 5 million bit memory, with operating speeds ranging from 50 milliseconds to one microsecond. Contact us for all your data storage needs.



Seneca Falls Mechanical Power Amplifier with two phase Servo Motor as control input device.

SHAPED AUTOMATICALLY BY THIS SENECA FALLS MECHANICAL POWER AMPLIFIER

Insulators, like the partially finished one pictured, used to be shaped by hand-held tools—much as a hobbyist operates a wood turning lathe. Now a Seneca Falls Two-Axis Servo Drive utilizing the Mechanical Power Amplifier shapes more insulators better, faster and at lower cost.

Whatever your control problem, investigate this simple, easily maintained Power Servo Drive that will amplify torque from *any* control input device. Its excellent dynamic response permits the design of high sensitivity control systems. Write for Technical Bulletin EE 1009.

The Seneca Falls MECHANICAL POWER AMPLIFIER is a simple, power servo drive in striking contrast to the more complex electrical and hydraulic devices. Years of Service in rugged applications prove its dependability, long life and negligible maintenance.

SENECA FALLS MACHINE
PIONEERS IN AUTOMATION

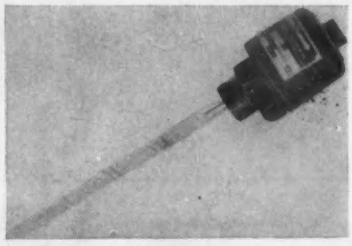
SENECA FALLS, MACHINE CO.
ELECTRONICS DIV. • SENECA FALLS, N. Y.

NEW PRODUCTS

(readout by standard megohmeter) proportional to concentration and magnitude of moment. Infinite life is possible with reasonable mechanical protection. Price: $10 for engineering samples.—Conrad-Carson, Inc., San Diego, Calif.

Circle No. 331 on reply card

CONTROLLERS, SWITCHES & RELAYS



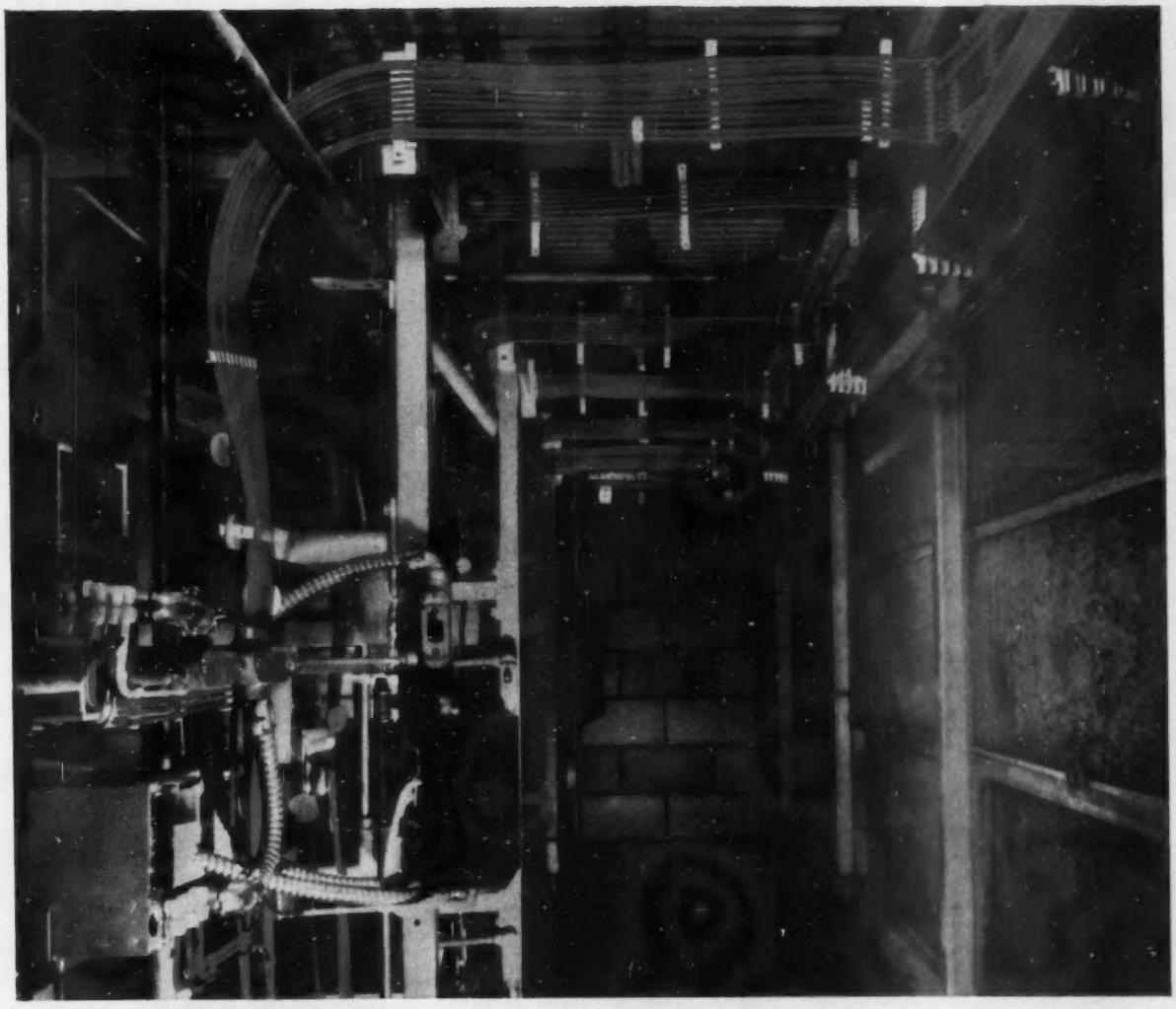
FLOW ACTUATED

Designed to start and stop pumps, valves, alarms, controls, etc. in mixing, blending systems, and the like, this new switch is actuated by the flow of the stream being monitored. The units fit lines from ¼ to 60 in. in brass, bronze, steel, or stainless steel. Various switching arrangements and various capacities are available.—Power Equipment & Engineering Co., Inc., Torrance, Calif.

Circle No. 332 on reply card

0.2-MICROSEC SWITCH

A new high speed ferrite switch capable of on-off or spdt switching in less than 0.2 microsec uses Faraday rotation to operate over a 10 percent bandwidth at X band without programming the drive current. Features include 0.7 db "on" insertion loss, 30 db "off" insertion loss or crosstalk separation, and power capability of



Plaskon NYLON INSTRUMENT AIR TUBING SAVES $30,000!

Plaskon Nylon ¼" tubing, shown above, led the way to a whopping $30,000 saving on a unique instrument-air control system for Allied's National Aniline Division, Hopewell, Va. plant. The savings on this 125,000 ft. job came from: (1) First cost averaging *half* that of ¼" copper tubing. Less costly supports, too. (2) Installation speed... *Flexibility* allowed long complex runs without fittings. (Coils come in 250 to 1000 ft. lengths.) Single or bundled tubes are easy to bend and snake through conduits. *Light weight* speeded handling... Plaskon Nylon weighs ⅛th that of copper, 1000 ft. of ¼" tubing weighs only 10 lb! *Other advantages*—Tubing of Plaskon Nylon has very high fatigue life... resists kinking. It resists atmospheric corrosion, many chemical environments, cyclic heating to 230°F. Will not contribute to electrolytic corrosion. Stocked in all standard I.S.A. colors. Can be carbon pigmented to resist sunlight.

Plaskon Nylon tubing can be joined by almost all types of metal-tubing fittings—flare or compression. Simple 90° bending clips and nylon multitube clips facilitate installation. Call or write for more details of the job described above, or for expert help on your own projects.

Allied Chemical makes only the Plaskon Nylon raw material; the tubing is available from many competent commercial extruders, in plastic sheathed, cabled bundles with or without armor.

PLASTICS AND COAL CHEMICALS DIVISION
40 Rector Street, New York 6. N. Y.

Allied Chemical

CIRCLE 227 ON READER SERVICE CARD 227

For Your Power Drive · Design · Application or Replacement Maintenance

There's a

T-J CYLINDER

That Can Assure

Accurate Efficient Operation

Only T-J's complete line can assure you a cylinder of either air or hydraulic application – with practically limitless design specifications for bore, stroke, pressure range and even delivery requirement. From the time-tested, standard tie-rod air and hydraulic, to the exclusive T-J Spacemaker, and including the recently introduced Squair Head, T-J cylinders give you more features for efficient, long-lasting operation. Write today!

Plus **THE ONLY**

COMPLETE ENGINEERING CATALOG LINE, TOO!

H-47 for standard tie-rod hydraulic cylinders.

SQ-1058-4 for the T-J Squair Head cylinder.

No. 54 for standard tie-rod air cylinders.

SM-56-3 for the incomparable Spacemaker cylinder.

HSM5-58-4 for the High-Pressure Hydraulic Spacemaker cylinder.

THE TOMKINS-JOHNSON CO. JACKSON, MICH.

CYLINDERS · MILLING CUTTERS · RIVETERS and CLINCHERS

NEW PRODUCTS

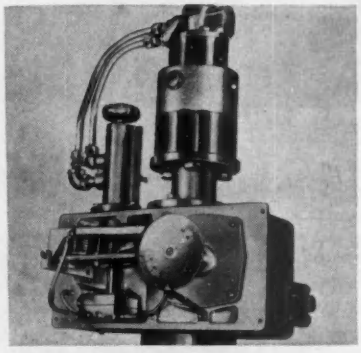
200 watts average. The switch is intended for such applications as pulse modulation of CW sources, TR tube replacement in high repetition rate radar systems, and diplexing of two sources in a common waveguide.—Hughes Aircraft Co., Components Div., Culver City, Calif.

Circle No. 333 on reply card

COMPUTES PNEUMATICALLY

The Force Bridge is a newly announced pneumatic computing relay available in models for squaring, square root extracting with pressure compensation, multiplication, division, multiplication and division, and ratio setting. The device works on a unique force-balance principle. The bridge consists of two weigh beams that rotate on a common movable fulcrum. This design keeps friction—and error—to a minimum: as low as 0.5 percent from 20 to 90 percent of scale. Simple installation requires only input and output tubing and 20-psi air supply.—Fisher & Porter Co., Warminster, Pa.

Circle No. 334 on reply card



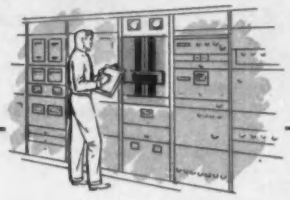
CONTROLS PUMPS

A new pneumatic controller is designed to bolt onto any of the manufacturer's Series 200, 400, or 600 run-adjust pumps. It accepts a linear, square root, or other exponential signal and has high sensitivity and rapid response (from 0 to 100 percent stroke in 7 sec. with a 30-psig plant air supply). The controller, on signal, adjusts the pump's stroke length to give varying rates of flow. Good accuracy is obtained without overshoot or hunting. Only 21 in. headroom is required.—Wallace & Tiernan, Inc., Bellevelle, N. J.

Circle No. 335 on reply card

the pb 250

a general purpose, microsecond computer for $30,000



The design of the PB 250 enables it to be mounted as a systems component in 31½ in. of a standard relay rack.

SPECIFICATIONS

TYPE
Serial, binary, internal program.

COMMAND STRUCTURE
Single address with index register. 46 commands.

OPERATION TIMES (22 bit word)

Add/subtract	12 μsec.
Multiply	276 μsec. (max.)
Divide	252 μsec. (max.)
Square root	252 μsec. (max.)

MEMORY
Type: Magnetostrictive delay lines.
Capacity: 1,808 words standard, expandable to 15,888 words.

INPUT-OUTPUT
Standard: Automatic typewriter, paper tape punch and reader, 30 control inputs, 32 control outputs, high-speed block input-output (85 KC word rate).
Optional: High-speed paper tape punch and reader, magnetic tape units (six maximum) employing IBM 700 series format, punched card equipment.

DIMENSIONS
30 in. high, 19 in. wide, 24 in. deep.

POWER REQUIREMENT
115 volts, 60 cycles, at 100 watts.

COMPLETELY SOLID STATE

Outstanding features of the PB 250 include:• MICROSECOND SPEED: Addition and subtraction require 12 microseconds. Multiplication takes 276 microseconds and division 252 microseconds.• EXPANDABLE MEMORY: Minimum capacity of 1,808 words, expandable to 15,888 words. External core memory of 16,384 words available.• COMMAND STRUCTURE: Versatile command list of 46 instructions.• SIMPLE PROGRAMMING: Internally programmed, single address instructions, command indexing, and automatic double precision operations.• INPUT-OUTPUT SYSTEMS: Automatic typewriter, paper tape reader, and punch standard. Complete range of peripheral equipment available.• EXCEPTIONAL RELIABILITY: Conservative solid-state design, small component count, and absence of moving parts.• SYSTEMS INTEGRATION: May be integrated into existing systems, on- or off-line. Ability to operate as universal format-to-format converter.

PACKARD BELL COMPUTER
A Subsidiary of Packard Bell Electronics
1905 Armacost Avenue, Los Angeles 25, California • GR 8-4247

• 3-7-60 PB

CIRCLE 229 ON READER SERVICE CARD 229

A NEW APPROACH TO MACHINE PROCESS CONTROL

Step Sequencing

the new **Eagle Step Switch**

use any type of time or sensing device to advance the *Eagle Step Switch*

PUSH BUTTON

LIMIT SWITCH

INTERVAL TIMER

PRESSURE CHANGE

LEVEL CONTROL

operate a multiplicity of load circuits in any combination up to 19 circuits

This new Eagle Step Switch also provides:

1 SEQUENCING INTERLOCK when used with multiple indexing circuits.

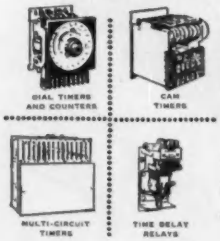
2 10 AMP SWITCH CONTACTS control load switches direct — no need for load relays.

3 MECHANICAL CIRCUIT INTERLOCK by cam action — eliminates interlocking relays.

4 115 VOLT COIL operates direct on AC with heavy duty ratchet mechanism — insures long life.

Write us regarding your count problem, or see your local phone directory or Thomas Register under the heading, "Timers, Electric" for your nearest Eagle Signal representative.

OTHER POPULAR HIGH QUALITY EAGLE TIME-COUNT CONTROLS



BLISS EAGLE SIGNAL COMPANY • Moline, Illinois

A DIVISION OF THE GAMEWELL COMPANY, AN E. W. BLISS COMPANY SUBSIDIARY

VISIT US AT THE PRODUCTION ENGINEERING SHOW SEPT 6-16, NAVY PIER, CHICAGO—BOOTH No. 381

MANUFACTURERS OF A COMPLETE LINE OF INDUSTRIAL TIME-COUNT CONTROLS

NEW PRODUCTS

PLUS . . .

(336) A magnetically actuated **proximity switch** that is water, oil, and explosion proof has been introduced by **Electro-Seal Corp.**, Des Plaines, Ill. . . . (337) **Kurman Electric Co., Subsidiary of Crescent Petroleum Corp.**, Brooklyn, N. Y., now has on the market an unusually sensitive **multipole relay** with operating power required as low as 25 mw per pole.

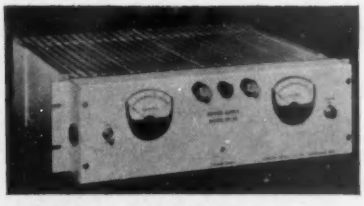
Circle No. 336 or 337 on reply card

POWER SUPPLIES

SMALL BUT POTENT

The Varia-Volt shown above is a sealed, static power supply that, in separate standard units, produces up to 20,000 volts. Input voltages are as low as 1.3 volts. Only 1 in. in diam and 3 in. long, the units are ideal for such applications as in portable scintillation counters, ionization chambers, oscilloscope supplies, or wherever miniature, high voltage supplies are needed.—Victory Electronics, Inc., Westbury, N. Y.

Circle No. 338 on reply card



COMPUTER SUPPLY

Completely transistorized, the Model RP-10 is a regulated 8-amp power supply especially designed and conservatively rated for computer applications. A special feature is a circuit that protects transistors in the load circuits from damaging voltages in case of malfunction within the supply; the circuit clamps the output to less

автоматический перевод
вычислительные машины
способствуют исследова-
нию языков

AUTOMATIC TRANSLATION
INDEXING
ABSTRACTING

To formulate rules for automatic language translation is a subtle and complex task. Yet, significant progress is being made. During the past several years large amounts of Russian text have been translated and analyzed at Ramo-Wooldridge's Intellectronics Laboratories using several types of existing general purpose electronic computers.

Many hundreds of syntactic and semantic rules are used to remove ambiguities otherwise present in word-for-word translation. The considerable improvements that have been effected during the progress of this work indicate that it may be possible within the next year or so to produce, for the first time, machine translation of sufficient accuracy and at sufficiently low cost to justify practical application. Electronic computers are also invaluable for other language research activities at Ramo-Wooldridge.

Techniques for automatic indexing, automatic abstracting, and other aspects of communicating scientific information are also being investigated. Research and development at the Intellectronics Laboratories will eventually lead to electronic machines capable of carrying on self-directed programs of research and analysis and "learning" by their own experiences.

The accelerating pace at which these "communication of knowledge" problems are growing in importance have created challenging career opportunities in new fields of scientific endeavor.

For a copy of our general career brochure, "An Introduction to Ramo-Wooldridge," write to **Dr. Richard C. Potter,** *Head, Technical Staff Development.*

RAMO-WOOLDRIDGE
a division of ***Thompson Ramo Wooldridge Inc.***
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BRYANT offers...
Storage at less than ½¢ per bit!
— with the Bryant 18.5" diameter Magnetic Storage Drum
Standard operating parameters include:
• Bit repetition rate over 200 KC (RZ)
• Dynamic runout: less than .0002" T.I.R.
• Range: 600 RPM to 1800 RPM • Number of tracks: 825 • Bits per track: 7500
• Design life: over 3 years at 1800 RPM
Write today for data and specifications on this and other Bryant Standard Magnetic Storage Drums. BRYANT COMPUTER PRODUCTS, 1200 Oakman Boulevard, Detroit 32, Michigan. Division of EX-CELL-O Corporation.

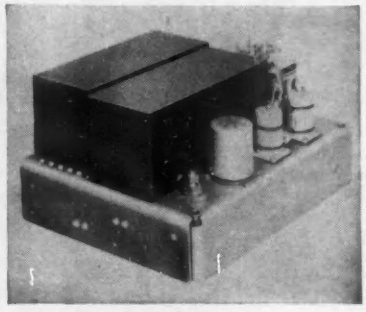
NEW PRODUCTS

than 25 volts and blows the supply fuse within 3 millisec.

Characteristics:

Input voltage: 117 volts ±10 percent
Frequency: 60 cps, single phase
Maximum input power: 280 watts
Output voltage: −16 volts, adjustment range of −3 to −19 volts
Dimensions: 5¼ x 10 x 11½ in. (h, w, d)
Weight: 38 lb
—Computer Control Co., Inc., Framingham, Mass.

Circle No. 339 on reply card



FOR COMPUTERS

Advanced circuitry in this precision power supply allows it to achieve performance needed for use with precision computing equipment, including the demands of inertial guidance integration. Outputs are plus and minus 25 volts, both within better than ±0.01 percent at 5-15 ma. Inputs required are 115 volts ±6 percent, 400 cps ±2 percent, 3 phase, 5 watts max; 28 vdc ±2 percent, 40 ma max; 28 vdc, unregulated, 7.5 watts. The D3907-01 supply weighs 8 lb and measures 8.823 x 7.025 x 4.472 in.—Kearfott Div., General Precision, Inc., Little Falls, N. J.

Circle No. 340 on reply card

HAS DUAL OUTPUT

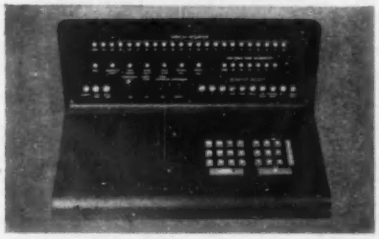
A new battery for missile and space vehicle use delivers two outputs in a package measuring only 5 in. square by 10.5 in. and weighing 12 lb. One 20-cell section provides 25 amps at 28 volts; maximum current is 100 amps with discharge time of 4 min. at 25 amps. Capacity is 1.7 amp-hr. The second section, also of 20 cells, supplies 28 volts at 46 amps; maximum current is 125 amps; discharge time is 4 min at 46 amps, and capacity is 3 amp-hr. Activation of both

CONSIDER ON-LINE COMPUTER CONTROL...

. . . for maximum plant efficiency
greater product uniformity
higher plant yield

CONSIDER DAYSTROM FOR . . .

systems analysis to assist you in determining the most feasible approach to solving your problems ■ single source responsibility — from a preliminary study to installation of instrumentation ■ a unique guarantee of 99% operational availability ■ unsurpassed experience in designing, building, and installing control systems **SEE US AT THE ISA SHOW,** Booth 1212, on the challenging problems of on-line control.



Nerve center of the Daystrom control system for the world's first fully-automated electric power generating station, to go on-line in January, 1961.

DAYSTROM, INCORPORATED
CONTROL SYSTEMS DIVISION
LA JOLLA, CALIFORNIA

CIRCLE 233 ON READER SERVICE CARD 233

•MACHINING AND PROCESS CONTROL
•COUNTING
•BATCHING
•SORTING
•MIXING

NEW!

HIGH-SPEED, SOLID-STATE, PRESET COUNTER

MODEL 300T

•WINDING
•PACKAGING
...or any other physical process that can be electrically digitized.

The completely transistorized Model 300T industrial counter is rugged, dependable and low-cost control instrumentation that is ideal for every use requiring a preset counting device. Modular design minimizes maintenance time and steel construction permits mounting directly on controlled machine. Modules can be easily modified for special applications. The 300T is a truly remarkable instrument that deserves your serious consideration.

Send today for complete technical information.

SPECIFICATIONS

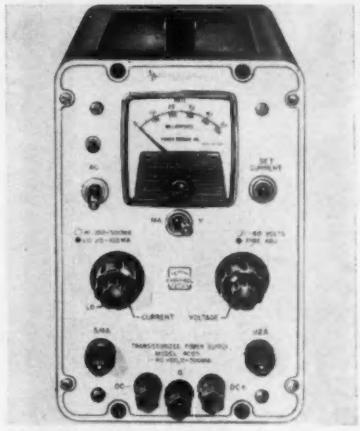
Speed: 6,000,000 counts per minute
Range: 1 to 9,999 standard. 5 to 8 decades available
Reset: Automatic, manual, local or external
Size: 3½" high; 9½" wide; 14" deep (standard model)
Weight: Approx. 10 lbs.

ERIE
INSTRUMATION
ERIE PACIFIC DIVISION • ERIE RESISTOR CORPORATION
12932 S. Weber Way, Hawthorne, California
Phone: ORegon 8-5418

NEW PRODUCTS

sections is automatic via a mechanism using an electrolyte tank and piston operated by a solid propellant gas generator. Time for activation is 1.0 sec; signal required is 2 amps at 28 volts.—Cook Batteries, Sub. of Telecomputing Corp., Denver, Colo.

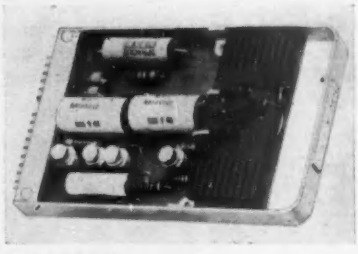
Circle No. 341 on reply card



COMBINES FOUR FUNCTIONS

The Model 4005 transistorized supply, first in a new line of universal regulated dc sources, combines the functions of four separate power supplies. It may be operated as a constant voltage source, a constant current source, a constant voltage source with automatic current limiting, or a constant current source with automatic voltage limiting. The supply covers the range of 1-40 vdc at 0-500 ma. Regulation is within 0.05 percent; ripple is less than 500 microvolts as a voltage regulator and less than 25 microamp as a current regulator. Unit measures 5¾ x 8⅝ x 11¾ in. (w,h,d). Price: $143.50—Power Designs, Inc., Westbury, N. Y.

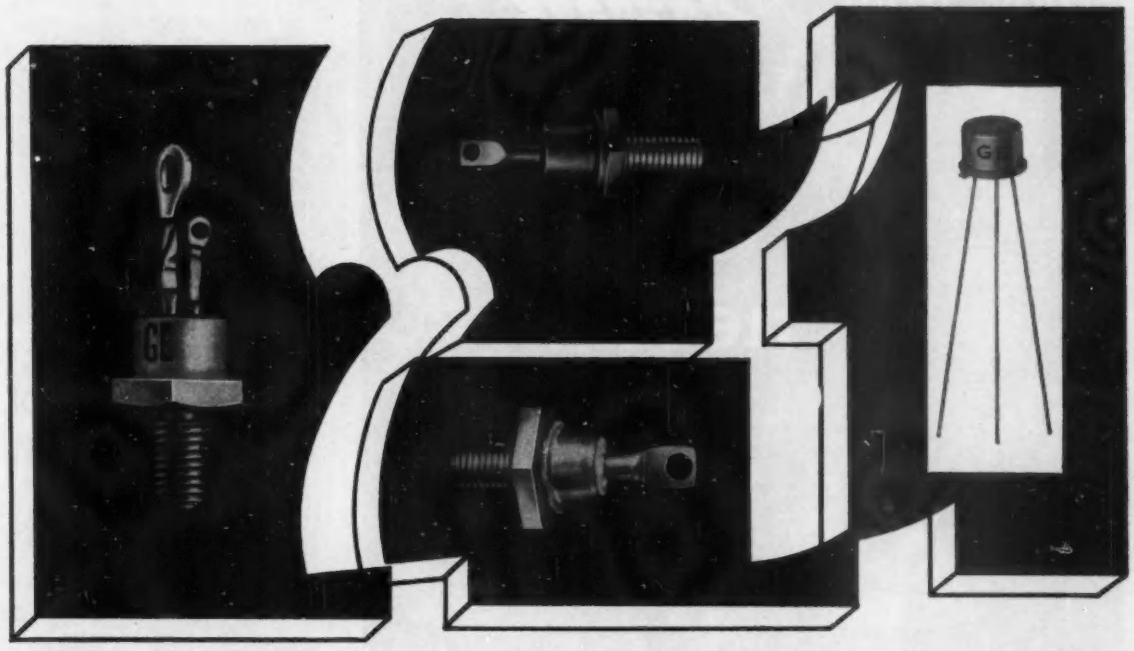
Circle No. 342 on reply card



PLUGS IN

These plug-in power supplies can be used for outputs from 10 to 35 vdc

How to fit proved



components into your SCR circuits

Hundreds of circuits have successfully proved out the General Electric semiconductors listed here as companions to the silicon controlled rectifier. In fact, General Electric used these very same components in developing and perfecting the revolutionary SCR. You capitalize on G.E.'s three years of unequalled SCR experience when you choose compatible G-E components. Together they form a seasoned, smooth-running team that will enhance the performance and reliability of your designs.

And remember, *only* G-E medium current rectifiers give you freedom from thermal fatigue (only hard solders are used); *transient* PRV ratings that save you money; reverse polarity for common heat sink mounting; and very low reverse leakage current for operation in series with SCR's.

For detailed information on SCR theory, ratings and applications, send $1.00 for General Electric's new *Controlled Rectifier Manual.* Also at many G-E Distributors.

CIRCUIT COMPATIBILITY CHART

If using G-E SCR Type	Use G-E Rectifier Type	Max. Cont. Current @ Stud Temp.	Peak 1 Cycle Surge	Max. Trans. PRV	Stud Hex. Size
C10	1N1341A-1N1348A	7A @ 140C	150A	800V	7/16"
C11	1N1341A-1N1348A	7A @ 140C	150A	800V	7/16"
C35	1N1199A-1N1206A* 1N2154-1N2160*	12A @ 150C 25A @ 145C	240A 300A	800V 800V	7/16" 11/16"
C36	1N1341A-1N1348A 1N1199A-1N1206A*	7A @ 140C 12A @ 150C	150A 240A	800V 800V	7/16" 7/16"
C40	1N1199A-1N1348A 1N2154-1N2160*	12A @ 150C	240A	800V	7/16"
C50	4JA60*	50A @ 160C	900A	500V	1-19/32" Dia. Housing
ZJ50L	4JA62*	50A @ 110C	900A	500V	1-19/32" Dia. Housing
Compatible Unijunction Firing Transistor: 2N1671A					

*Stock Assemblies Available

GENERAL ELECTRIC

Semiconductor Products Dept., Electronics Park, Syracuse, N. Y.

Standard Tatnall cells for popular applications. Designed and built to give you unsurpassed standard cell performance and value. Both universal and compression type cells in several ranges available off-the-shelf for new or replacement applications.

Tatnall "Function-Fitted" transducers custom-built to your needs. You specify application, accuracy, size, encasement, temperature compensation, corrosion resistance and other design, construction and performance features. You get ample, dependable performance . . . delivery matched to your schedule . . . and high economy, *because you pay only for the features you need.*

Budd technical and engineering service is available to help you determine your transducer requirements, select the best method of meeting them, and apply Tatnall cells with highest effectiveness. We invite you to write or call for a frank discussion of your needs.

INSTRUMENTS Budd DIVISION

THE BUDD COMPANY • P.O. Box 245 • Phoenixville, Pa.

Consult your phone book for sales offices in: Atlanta, Ga., Oak Park, Ill., Boston, Mass., Detroit, Mich., Seattle, Wash., Dallas, Tex., Los Angeles, Calif., San Francisco, Calif.

In Canada

Tatnall Measuring and Nuclear Systems, Ltd., 46 Hollinger Rd., Toronto 16, Ont.

236 CIRCLE 236 ON READER SERVICE CARD

with continuous current of 0-0.5 amp. Line and load regulation is within 0.75 percent. Ripple is less than 1.5 mv. Completely self-contained except for transformer and voltage adjustment pot, 17 of the individual card supplies can be stacked together to give a total of 8.5 amps in a 3½ x 10 in. panel space.—Plug-In Instruments, Inc., Nashville, Tenn.

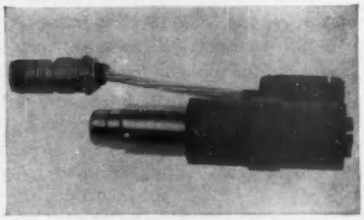
Circle No. 343 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS

SHORT MODEL

Newest addition to a line of Size 8 servomotors is the shortest version on the market that is wound for 115-volt sources. It is just 0.840 in. long and weighs 1.1 oz. Rotor inertia is 0.18 gm-cm^2; stall torque is 0.22 oz-in.; an acceleration at stall is 86,500 rad per sec^2, said to be three times greater than any equivalent unit. —Helipot Div., Beckman Instruments, Inc., Fullerton, Calif.

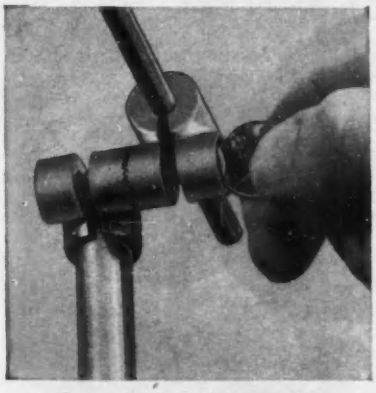
Circle No. 344 on reply card



EMERGENCY ACTUATOR

A new miniature size electromechanical actuator provides a "Hammer Blow" to operate switches, valves, etc. in emergencies. Originally developed to meet military requirements and

● **Build high strength rod, tube and pipe structures in minutes**



● **Save design and machining time on precision assemblies and fixtures with new**

Rotocon
TRADEMARK
ASSEMBLERS

"Like genies from a lamp," says one pleased user of new **Rotocon** assemblers. Speed and ease of assembly, superior strength, and infinite adjustability recommend **Rotocon** assemblers for numberless applications IN LABORATORIES, INDUSTRY, INSTRUMENTATION, AUTOMATION.

Rotocon assemblers grip rods, tubes and pipes in a tight ALL-AROUND GRIP that never burrs, scores, or distorts. Toothed faces of paired units FORM RIGID JOINTS AT ANY 10-DEGREE INCREMENT, not just right angles. Only a screwdriver (or even a coin) is needed to tighten the fastening screw into the nesting nut.

With the exclusive SNAP-CLAMP unit, additions to structures or fixtures can be made without disassembling any parts. This snap-on clamp affords the same ALL-AROUND GRIP as other assemblers in the line.

With so many uses in so many fields, **Rotocon** assemblers have to be seen, held in hand, and experimented with to reveal the time and money they can save you.

Sample Offer: A written request on your letterhead will bring you a sample kit of Rotocon assemblers, free and postpaid.

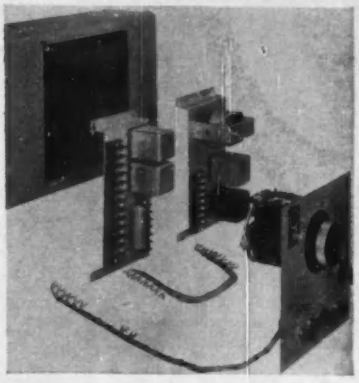
Rotocon Division
UNISTRUT PRODUCTS COMPANY
937 West Washington Blvd., Chicago 7, Ill.

CIRCLE 134 ON READER SERVICE CARD

NEW PRODUCTS

now available for commercial uses, the actuator operates on an input as low as 1.5 amps at 20 volts and releases an initial mechanical force of 70 lb. A range of electrical and mechanical variations is available.—Electro-Seal Corp., Des Plaines, Ill.

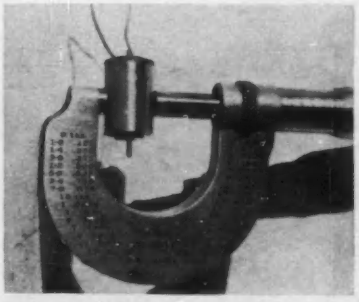
Circle No. 345 on reply card



MODULAR DRIVES

Individual unit design of relay panels, rectifier panels, and control panels, as shown in the photo above, provides greater flexibility for a line of adjustable speed drives. The new Series 35 includes dc motor drives employing adjustable autotransformers in combination with full wave rectifiers to attain variable speed adjustments over a wide range. A Size I is available for ½ hp maximum, and three other sizes are offered.—Cleveland Machine Controls, Inc., Cleveland, Ohio.

Circle No. 346 on reply card

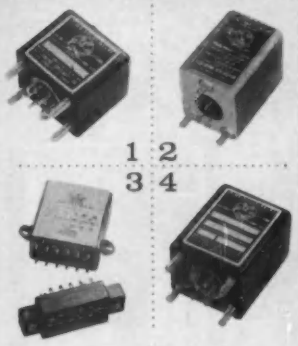


MINIMOTOR

Demonstrated above is the extremely small size of a 3-vdc motor said by its designer to be the smallest motor ever made commercially. It is just over ⅜ in. long by ⅜ in. in diam. Motor weighs less than ¼ oz and, with a 1,000 to 1 reduction gear, 1 oz addi-

CONTROLS

BUILDING BLOCKS FOR THE SPACE AGE
by
ELECTRONIC SPECIALTY CO.



1 STATIC TIMER—TS 00-000
Operation.....100 ms to 90 seconds —make or break
Temperature.....—65°C to 125°C
Vibration.....20 g's to 2000 cps
Shock.....50 g's in all planes
Life.....>1,000,000 cycles
Output.....SPST 100 ma. to 1 amp
Voltage.....18 to 30 vdc
Weight.....Less than 4 oz.

2 FREQUENCY SENSOR—RY-488
Designed per customer specifications
Temperature.....40°F to +125°F
Contact rating.....up to 10 amp
Over-voltage.200 V rms for 10 msec. to 130 V rms for 1 hour
Weight.....6 oz. to 12 oz.

3 6 PDT SOCKET RELAY—AHG3ES200AA
Contact rating.....10 amp
Vibration.....10 g's to 2000 cps
Temperature.....—65° to +125°C
Weight.....6 oz. max.
Altitude.....>80,000 ft.
Shock.....25 g's all planes
Nominal.....28 vdc
Pick up.....18 max.

4 TIME DELAY RELAY
(72 Hr. Delivery) T-010-000
Operation.....100 ms to 90 sec.
Reset time.....50 msec.
Contact rating.....10 amp. res, 3 amp. ind. (MIL-5757-C)
Operating voltage.....18 to 30 vdc (MIL-E-7894)
Temperature.....—65°F to +250°F
Shock.....30 g's (11 msec.)
Operating life.....100,000 operations

ES engineers welcome the opportunity to furnish an engineering estimate on your specific requirement. Emergency circumstances given special consideration. Ask for the RELAY DIVISION design folder.

ES

RELAY
DIVISION
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CORPORATE OFFICES
5121 San Fernando Road
Los Angeles 39, California
CHapman 5-3771

CIRCLE 237 ON READER SERVICE CARD

NEW

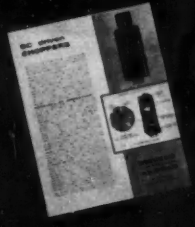
DC driven CHOPPERS

What... No AC?

In transistorized d-c amplifiers, the use of a d-c driven Chopper instead of the usual a-c drive, removes an additional source of stray a-c signals from the critical chassis wiring. The 94 cycle chopping rate also eliminates the null off-sets resulting from the use of a 60 cycle chopping rate.

In portable d-c amplifiers, the advantages of low level operation plus a 94 cycle chopping rate are now available, using a 12, or 24 volt battery as the chopper drive source.

Write for Catalog 554.



STEVENS INCORPORATED ARNOLD

QUALITY SINCE 1943

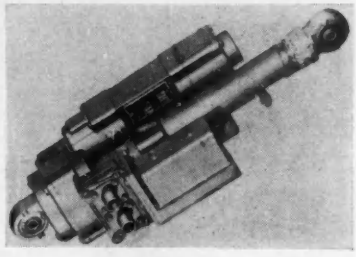
7 ELKINS ST., SOUTH BOSTON 27, MASS.

S/A-20-56

NEW PRODUCTS

tional. Maximum speed is 10,000 rpm; 2,000-rpm torque is 5 gm-cm, current is 0.2 amp. Price in lots of 1-10: $40.—Gordon Rosekilly Machinery, San Mateo, Calif.

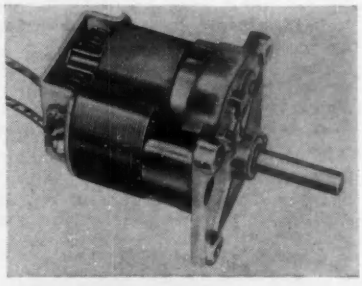
Circle No. 347 on reply card



LINEAR POWER

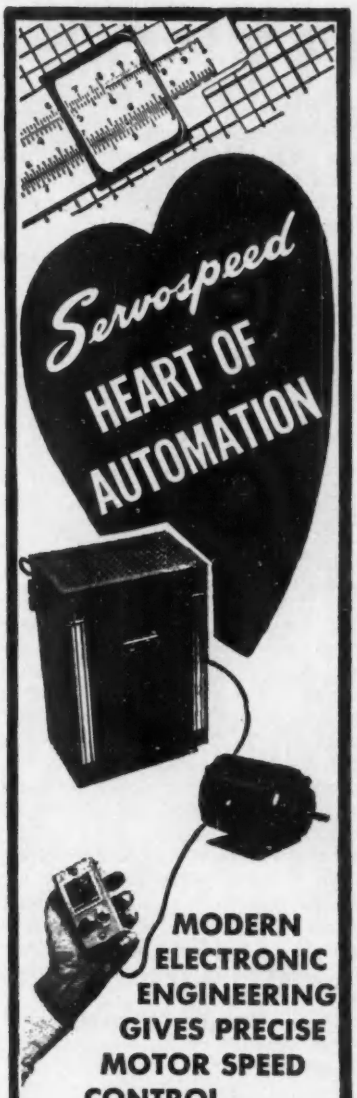
Originally designed for a wing flap system, this linear power actuator is suitable for a wide range of aerospace and industrial applications. The 26-vdc device features a high efficiency long life, close tolerance modified acme jackscrew, and an electrical load sensing device coupled to an electromagnetic clutch-brake. The unit thus senses, shuts off, and holds a predetermined load. Specifications include: normal load, 2,000 lb; maximum load, 5,400 lb; rate of travel, 0.46 ips; stroke, 6.75 in.—Hoover Electric Co., Los Angeles, Calif.

Circle No. 348 on reply card



FAST STARTER, STOPPER

High torque characteristics are combined with split-second starting and stopping ability in the lightweight, low speed Rotorac motors now available. Operating from a 60-cps source, the motors can deliver 6 lb-in. of torque at 20 rpm for a 0.75-amp, 115-volt input. Typical weight for the motors is only 10 oz. The units also feature the ability to sustain stall conditions without damage and to accommodate reasonable adjustments in



MODERN ELECTRONIC ENGINEERING GIVES PRECISE MOTOR SPEED CONTROL

1/100 — 10 H. P.

Modern industrial electronic engineering has been coordinated with electric motor design to provide a versatile means for obtaining the full possible advantage of speed control in DC motors while operated from the regular alternating current power line. Grid controlled "Thyratron" tubes are utilized for power controlled stepless variation to supply motor armature power. Patented feedback, or "Servo" circuits provide constant torque capability over wide speed ranges of as high as 60 to 1 in some models and a minimum of 20 to 1 in others.

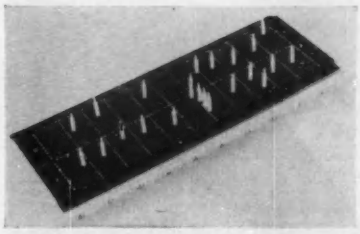
Servospeed
DIV. of ELECTRO DEVICES, Inc.
4 Godwin Ave., Paterson, N. J.
ARmory 4-8989

CIRCLE 135 ON READER SERVICE CARD

their speed-torque characteristics. A variety of types is offered.—Airborne Accessories Corp., Hillside, N. J.

Circle No. 349 on reply card

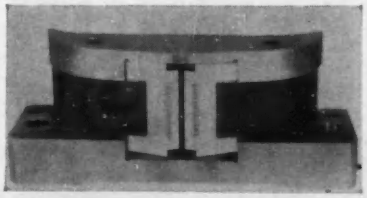
COMPONENT PARTS



PIN THE BOARD

Newly announced programming pinboards as shown above are memory matrixes into which digital information may be inserted. The technique is applicable to code conversion, signal routing, data system programming, and tape search equipment. The pinboards consist of two contact strips (one horizontal, one vertical) drilled and aligned to accept diode pins. Practically any size and configuration board is available; size of the basic pinboard is 13 x 50 columns, but this may be increased.—Beckman Systems Div., Beckman Instruments, Inc., Anaheim, Calif.

Circle No. 350 on reply card



EFFICIENT HEAD, GUIDE

High efficiency, both in recording and playback of digital data, is the result of the use of a unique core design in the construction of a new magnetic tape head. Gap length of the head is 10 microin., which allows it to be used at extremely high bit densities on the order of 6,000 flux reversals per in. in contact. The head is shown above

AVIONICS

BUILDING BLOCKS FOR THE SPACE AGE
by
ELECTRONIC SPECIALTY CO.

1 SEQUENCE PROGRAMMER—T-297-1
Designed for Drone Applications
Operation.....4 output pulses at 28 vdc ±10%— sequence to order
Temperature.....—65°F to +165°F
Shock.....50 G's—11 msec.
Output.....2.0 amp. @ 28 vdc
Altitude.....>80,000 ft.
Power Consumption.....5 watts max.
Life.....>1,000,000 operations

2 BOOSTER RELEASE TIMER—T-249
Operation.....9.25 ±0.25 seconds
Temperature.....—65°F to +160°F
Shock.....50 G's 11 msec. any plane
Acceleration.....40 G's any plane (constant)
Contacts.....10 amp res, 5 amp ind.
Voltage.28 vdc ±10% battery supply
Construction.....hermetically sealed

3 STATIC INVERTER—PS-105
Designed for Missile Application
Input.....28 vdc at 18 amps max.
Output.....no load—126 V rms 400 cps min. full load —115 V rms 400 cps max.
Load.....120 va max. on any phase, 300 va total
Efficiency.....>60% for full load
Altitude.....>150,000 feet
Shock.....10 G's any axis—30 G's crash safety
Temperature.....—55°C to +71°C

4 COMPLEX INTERVALOMETER—T-270
Designed for A.S.W. Application
Operation.....8 individual delays
Time delay.....150 msec. ±0.50 sec.
Contact rating.....5 amp resistive
Voltage.....18 to 30 vdc
Weight.....3.5 lbs.

ES engineers welcome the opportunity to furnish an engineering estimate on your specific requirement. Emergency circumstances given special consideration. Ask for the AVIONICS DIVISION design folder.

ES

AVIONICS
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CIRCLE 239 ON READER SERVICE CARD

ELIMINATE
MATHEMATICAL COMPUTATIONS...
W&T PRECISION MERCURIAL MANOMETERS

Simple knob adjustment eliminates temperature and gravity corrections. Forget about indexing the mercury well for each reading. W&T's specially graduated manometer scale automatically compensates for well level depression.

The Wallace & Tiernan FA-187 mercurial manometer also gives you:

- ★ Accuracy 1/5000
- ★ Range 0 to 31.5″ Hg or equivalent
- ★ Readings to 0.005″ Hg
- ★ Magnifying eye piece for exact reading
- ★ Magnetic vernier eliminates meniscus reading
- ★ Specially calibrated scale

Use the W&T mercurial manometers as calibrating standards for absolute pressure or easily modify them to perform as barometers, differential or vacuum indicators.

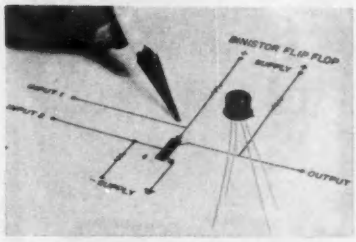
For further information, write Dept. A-128.28

WALLACE & TIERNAN INCORPORATED
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

NEW PRODUCTS

mounted in the company's new tape slot guide which features exceptionally good guidance along with reductions in tape curl and wear.—Shepherd Industries, Inc., Nutley, N. J.

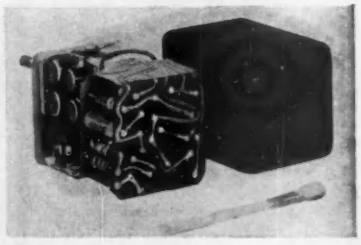
Circle No. 351 on reply card



A NEW SEMICONDUCTOR

The binistor is the name given to a major new silicon semiconductor device for use in switching and storage circuits. The bistable device performs as a flip-flop but with vastly reduced complexity. A typical flip-flop with two transistors, seven resistors, two capacitors, two diodes, and 28 solder connections can be reduced to one binistor, three resistors, and 10 solder joints. The NPN tetrode can operate from −80 to +250 deg C. Speed of the device, currently slower than that of high frequency transistors, is adequate for general purpose switching.—Transitron Electronic Corp., Wakefield, Mass.

Circle No. 352 on reply card



SMALLER SERVOAMP

Said to be one of the most compact servoamplifiers available, the tiny (0.9 cu in.) unit shown above was originally developed to drive part of an attitude indicator. In addition, it is suitable for use in computing instruments and other applications requiring an amplified signal for driving a 400-cps instrument servomotor. Other features include choice of phase shift characteristics (0 or 90 deg) and externally adjustable gain (nominally

ACCURACY TO 0.1%

4-100 SERIES

TAVIS
DeCeducer
D.C. INPUT
D.C. OUTPUT VARIABLE
RELUCTANCE TRANSDUCER

Models now available with ±0.1% static accuracy and temperature controlled packaging.

PROVEN APPLICATION

For use in control systems and testing applications where long term stability, accuracy and dependability under extreme environmental conditions are a must.

- in missiles for control, data recording and testing applications.
- in aircraft for testing, remote read-out and data recording applications.
- in industrial applications for data recording, remote read-out, remote control systems and testing applications.
- in telemetry for use with voltage controlled oscillators.

Write today for your Tavis Data Sheets on:

DIGIDUCER — Digital output pressure Transducer

ACEDUCER — 60 CPS input, D.C. output, 0.1% secondary pressure standard

Sub carrier oscillator and integral pressure Transducer

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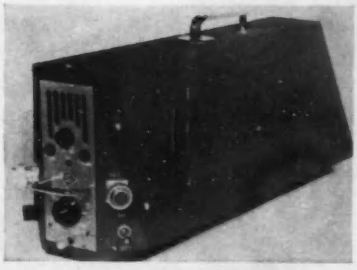
SUBSIDIARY OF EDCLIFF INSTRUMENT
1711 S. MOUNTAIN AVE. • MONROVIA, CALIF.

CIRCLE 136 ON READER SERVICE CARD

NEW PRODUCTS

300 for input impedance of 5,000 ohms, but gain of up to 1,500 is possible for low impedance). Lear, Inc., Grand Rapids, Mich.

Circle No. 353 on reply card



LOW LEVEL AMPLIFIER

A new wideband amplifier has been designed to amplify signals from strain gages, thermocouples, and other low level signal sources in accurate data acquisition and processing systems. Bandwidth of dc to 40 kc is unaffected by gain setting or load resistance; maximum noise level is less than 12 microvolts to 50 kc. Minimum input impedance is 100,000 ohms over entire band. Output is ±50 volts at ±50 ma. Common mode rejection is 130 db to 100 cps, capable of rejecting common mode signals up to 200 volts. Computer Engineering Associates, Inc., Pasadena, Calif.

Circle No. 354 on reply card

PLUS . . .

(355) Small general purpose **memories** from **Telemeter Magnetics, Inc.**, Culver City, Calif., are priced from $5,350 for a 128-word unit to $10,450 for a 1,024-word unit. . . . (356) New miniature **electric brakes and clutches** for instrument power drives rated up to 1.5 lb-in. are now available from **Warner Electric Brake & Clutch Co.**, Beloit, Wis.

Circle No. 355, 356 on reply card

ACCESSORIES & MATERIALS

ELECTRONIC GRADE MgO

Said to be purer by a factor of 10 or even 15 than any previously made,

MOTORS ACTUATORS

BUILDING BLOCKS FOR THE SPACE AGE
by
ELECTRONIC SPECIALTY CO.

1 **MODEL D-1212—Designed for 2nd stage Minuteman guidance system**
Horsepower 3.95
Power ..... 26 vdc
Weight ..... 6.3 lbs.
Weight with filter ..... 8.8 lbs.
FEATURES:
Excellent h.p./wt. ratio • Reduced size • Advanced design • High history of reliability

2 **MODEL D-1115—Designed for F-104 pilot seat actuator (Mil-E-5272 A)**
Power ..... 26 vdc (or 400 ac)
Weight ..... 8.5 lbs.
Travel ..... 0.34 in./sec.
Stroke ..... 4.5 in.
Normal Load ..... 400 lbs. total
Compression Load ..... 4100 lbs.
Tension Load ..... 12,000 lbs.

3 **MODEL D-822—Designed for F-104 trailing edge slat actuator**
Normal Operating load . 26,000 in.lbs.
Max. Operating load . 52,000 in. lbs.
Ultimate Static load . 75,000 in. lbs.
Travel ..... 45° at 0.625 rpm
Amperes
4 amps at 26,000 in. lbs. at 480 cps on 200 volts
Weight ..... 35 lbs.

4 **MODEL D-1029-1—Designed for pump applications, antenna drive systems, actuators and stabilizer applications**
Terminal voltage ..... 26.6 vdc
Horsepower ..... 6 hp
Speed ..... 7500 rpm
Duty cycle:
4.5 hp for 7.5 min.—6.0 hp for 20 sec.—2.0 hp for 30 min.
Weight ..... 20 lbs.

ES development engineers welcome the opportunity to furnish an engineering estimate on your specific requirement. Emergency circumstances given special consideration. Ask for the EEMCO DIVISION design folder.

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ELECTRONIC SPECIALTY CO.
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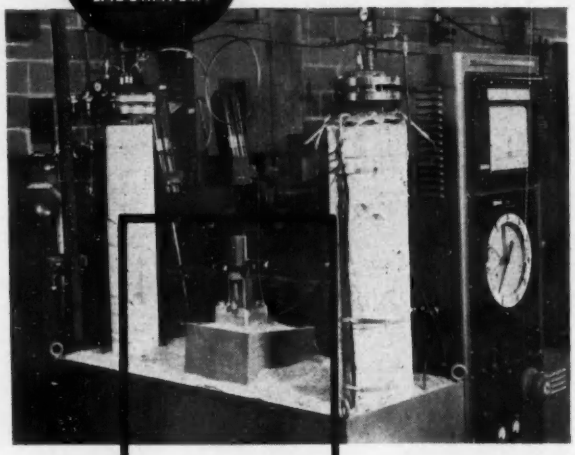
CIRCLE 241 ON READER SERVICE CARD

P-K Paul Venturi-Ball Valve Specified By

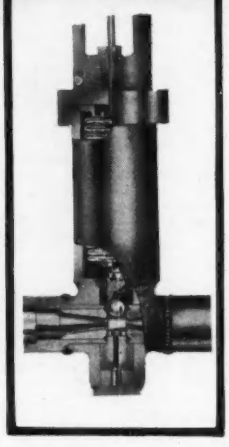
CASE HISTORY

ARGONNE NATIONAL LABORATORY

ARGONNE NATIONAL LABORATORY



P-K Paul Liquid Metal Valve in test loop under maximum temperature and pressure conditions at Argonne National Laboratory test site.



4" 1500 lb. Manually Operated Barstock Valve of 316SS, Stellited trim, with Bellows Seal and Extended Bonnet.

FOR 1600°F LIQUID SODIUM SERVICE

A year and a half ago Argonne National Laboratory selected a stock P-K Paul Liquid Metal Valve for testing and evaluation. Experience gained in testing this valve led to the purchase of five additional valves of this type for use in the TREAT "In-Pile Sodium Loop". Their use for this difficult service — tight shut-off of liquid sodium at operating temperatures above 1000°F — **illustrates again the superior performance of the unique Venturi-ball design.**

The P-K Paul Valve offers high flow capacity, wide rangeability, straight through non-turbulent flow, low operating thrust, self-purging characteristics, high resistance to erosion, abrasion and corrosion, and, most important in this application, positive shut-off.

For specification and application information on the complete line of P-K Paul Valves, write today for General Catalogue GV101.

General Kinetics Corporation

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NEW PRODUCTS

electronic grade magnesium oxide has now been made available. Up to now MgO has been grown for optical purposes. Now there is evidence that the material will be a future high temperature semiconductor material and the primary maser material. Its melting point is 3,080 deg C. Ultrapure MgO can thus be used in semiconductor devices because of its stability at high temperature. Doped MgO can be obtained from a grown junction and used as barrier devices. —Semi-Elements, Inc., Saxonburg, Pa.

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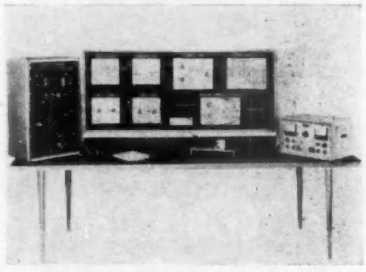
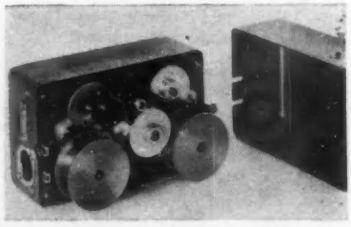


PACKAGED LABORATORY

Laboratory for Servomechanisms is the tradename for the packaged laboratory shown above that has been introduced to meet the requirements of colleges and industry for instruction, demonstration, and development of feedback control systems. The integrated system is complete with all components, test apparatus, and manuals required to perform all liner —and many nonlinear—feedback control experiments. The lab uses modular components connected by patch cords for the construction of systems. —Superior Mfg. & Instrument Corp., Flushing, N. Y.

Circle No. 358 on reply card



PROGRAMS AUTOMATICALLY

Shown above is the new 8-channel, time base punched tape programmer for automatically programming standard teletype punched tape. The

Teletype machines help cut costly paperwork

A Teletype machine equipped with a simple sprocket-feed mechanism can handle multi-carbon forms as readily as the more familiar plain paper on which messages are transmitted. Thus distances can be bridged not only with information, but with information that is preprocessed, ready to go to work.

Example: A sales order is transmitted from branch office to home office and reproduced accurately and precisely on a form in the Teletype machine—with carbons for production, accounting, shipping, etc. No further order-writing effort needed, no recopying errors.

Teletype printers handle a wide variety of multi-copy forms. Moreover, the usefulness of this technique can be further extended with Teletype tape punching and reading equipment—which can capture, store and utilize repetitive data to further mechanize paperwork procedures.

Teletype Corporation manufactures this equipment for the Bell System and others who require the finest in data communications equipment.

Typing Tape Punch

Tape Reader

Send-Receive Page Printer

Automatic Send-Receive Set

FREE Model 28 line folder. Write Dept. 263
5555 Touhy Avenue, Skokie, Illinois.

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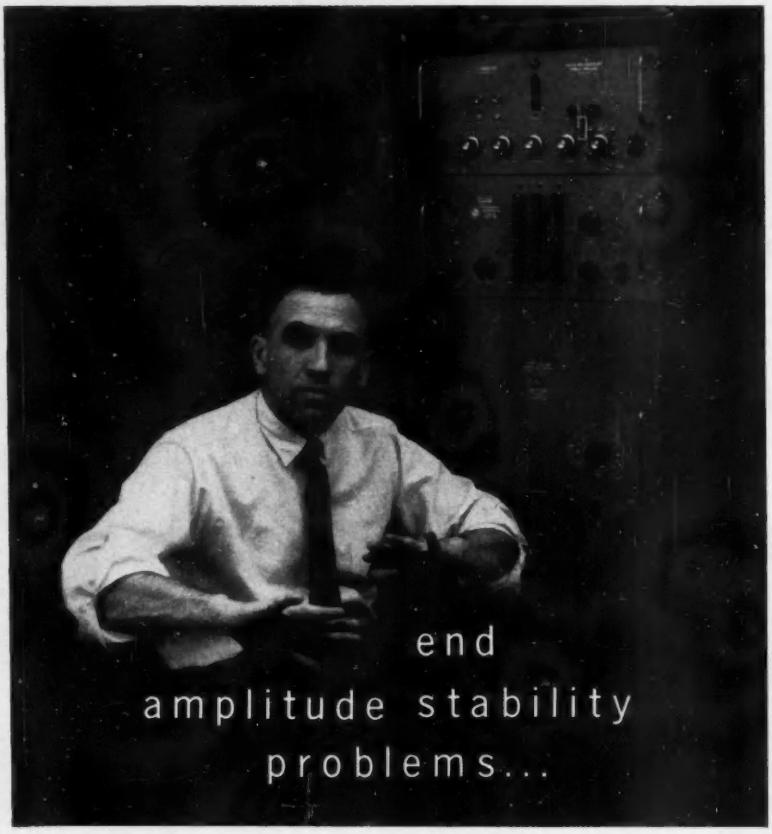
CORPORATION
SUBSIDIARY OF *Western Electric Company* INC.

CIRCLE 243 ON READER SERVICE CARD



with this new low-distortion

ac power source!

New from Krohn-Hite: this variable-frequency, 50 watt ac power source, with the long-desired specifications of less than 0.01% amplitude stability and 0.1% harmonic distortion! The LDS-1500 offers a continuously variable wide range of voltage and current — up to 1500 volts, and up to 12 amps, at *any* frequency from 20 cps to 20 kc.

The short-term stability and low distortion now makes it possible for you to calibrate conventional indicating ac voltmeters and ammeters, and digital meters to lab standards, yourself!

As a general-purpose variable frequency source of distortion-free, highly stable power, the LDS-1500 has many applications. Distortion measurements at high power levels of precision resolvers, inductors, gyro motors and other electro-magnetic components can now be made with greater accuracy and ease.

The 50 watt power output of the LDS-1500 is ample to supply test benches, for quality control testing at unusual frequencies.

Investigate this unusual ac power source. Its unsurpassed stability and distortion characteristics, its convenience of continuously variable frequency, voltage and current — make it a basic instrument of the industry. Send for complete technical specifications.

KROHN-HITE CORPORATION

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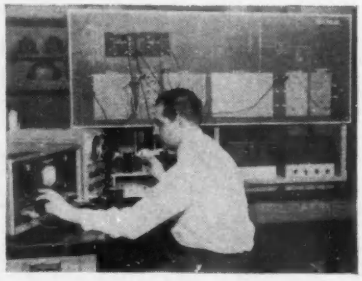
NEW PRODUCTS

device provides precision time base programming with 20 min of programming at a standard tape speed of 1 ips. Completely self-contained, the unit measures 5 x 8 x 6 in., including storage space for reels to hold 100 ft of tape. Output is an 8-channel switch closure with common return insulated from chassis ground. Separate motors are used for forward drive and automatic rewind. Price: $875.—Anaheim Electronics Div., Electronic Engineering Co. of Calif., Santa Ana, Calif.

Circle No. 359 on reply card



SELF-CONTAINED TEACHER

A new instructional device called the Controlab is designed to simplify teaching feedback control system design and testing for colleges and in-plant training. Using Controlab the student actually constructs a system by wiring between points on diagrams displayed on a patch panel board. The system contains all necessary electronic, mechanical, and electro-mechanical components and equipment. The technique was developed by Prof. Vincent Del Toro of the City College of N. Y.—Shaw Controls, Inc., Garden City Park, N. Y.

Circle No. 360 on reply card

SYSTEMS

20 TIMES FASTER

The advanced solid state 7074 data processing system is twice as fast in business data processing and up to 20 times as fast in scientific computations as the manufacturer's 7070 system. But typical 7074 systems will sell or rent for only about 22 percent more than 7070's. In addition, any 7070 can be converted to a 7074 on site by

the replacement of three 7070 modules with two high speed 7074 components. The 7070 programs can be applied directly to the 7074. Fixed point processing speeds for the 7074 (in operations per sec): addition or subtraction, 100,000; multiplications (10 × 5 digits), 23,250; logical decisions, 250,000. Floating point speeds: addition or subtraction, 62,500; multiplication, 16,667; division, 10,400. Core storage access time is 4 microsec; core to core transmission rate is 1.25 million digits per sec. Price: $1,284,350 or $29,300 rental per month.–International Business Machines Corp., Data Processing Div., White Plains, N. Y.

Circle No. 361 on reply card

DATA ARE COMPATIBLE

Data output that is directly acceptable to most computers is the feature of a new, low cost, high speed, low level differential data acquisition system. Modular design of the solid state system allows acceptance of all types of electrical signals. Components of the basic system are a new high speed scanner in 10 channel multiples, a high speed analog to digital converter, and a new output format control. Inputs which may be connected without preamplification include thermocouples; strain gages; and pressure, flow, and level transducers. Scanning speed is 600 channels per sec. – Electro Instruments, Inc., San Diego, Calif.

Circle No. 362 on reply card

DECIMAL CONTROL

Absolute decimal control is used in the new Model 600 numerical positioning system for point to point positioning of machine elements. Input to the

CIRCLE 245 ON READER SERVICE CARD→

NEED A TAPE RECORDER?

CEC has five *new* recorders and more coming soon! For 14-channel record and reproduce capability in an instrument with all solid-state electronics, look into the new PR-2300 Portable Recorder – it goes anywhere in just 30″ of vertical RETMA rack space.

CEC's new DR-2700 Digital Recorder/Reproducer is 100% transistorized with tape speeds to 150 ips and command rates to 200 per second, with unrestricted programming.

And here's a new improved version of CEC's most famous Recorder/Reproducer . . . the GR-2500. It handles Analog, FM, PDM, CM, and digital modes, has interchangeable plug-in amplifiers.

Engaged in critical data analysis? Rely on CEC's new GL-2510 Continuous-Loop Recorder / Reproducer – with 14 Analog, FM, or PDM plug-in amplifiers and six tape speeds from 1⅞ through 60 ips.

Completely mobile and ideal for airborne use, the new AR-2100 Recorder provides 14 channels in Analog, FM or PDM modes...all in a rugged, lightweight die-cast case.

Rounding out CEC's line of tape instrumentation equipment is the 5-055A Automatic Tape Degausser. This new unit accepts reels from 7″ to 14″ dia. and widths from ¼″ to standard 2″ TV tapes. Erases to -70 db.

FOR MORE INFORMATION: PR-2300 Portable Recorder – Bulletin CEC 2300-X5; DR-2700 Digital Recorder / Reproducer – Bulletin CEC 2700-X1; GR-2500 Recorder / Reproducer – Bulletin CEC 1576-X1; GL-2510 Continuous-Loop Recorder / Reproducer – Bulletin CEC 2510-X1; AR-2100 Mobile & Airborne Recorder – Bulletin CEC 2100-X1; and 5-055A Automatic Tape Degausser – Bulletin CEC 1631-X1 – or call any CEC sales & service office.

DataTape Division CEC

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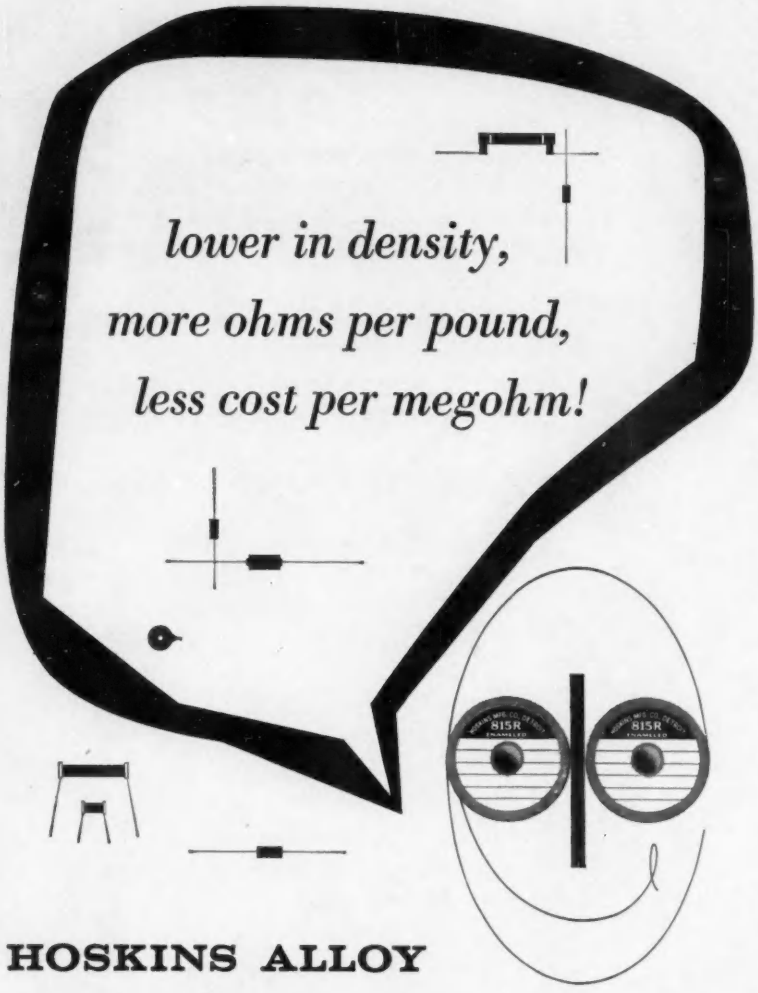

HOSKINS ALLOY

815-R Precision Resistor Wire

12.8 to 14.1% more ohms per pound! 10.8 to 12.7% less cost per megohm! These are worthwhile savings you can realize by using Hoskins Alloy 815-R in your precision wire-wound resistors. It's lower in density, has higher resistivity than standard 800-ohm nickel-chromium alloys. Yet it possesses comparable strength, ductility, resistance to corrosion. Its low temperature coefficient (0 ±10ppm per °C. from −65° to +150°C.)* is inherently controlled in the melt, rather than by "aging", to assure optimum uniformity. And it's available now bare or enameled in wire sizes ranging from .0031″ down to and including .0004″ to meet your particular application requirements.

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**Wire controlled to 0 ± 20ppm/°C. also available at greater savings—up to 19.6% lower cost/megohm.*

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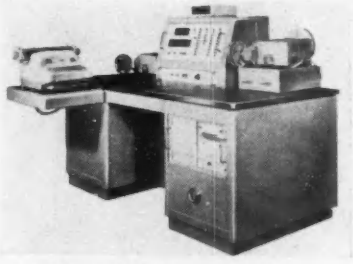
NEW PRODUCTS

controller can be by rotary decimal dials, full keyboard, 10-key keyboard, or eight-channel punched tape. Tape code is standard eight-channel prepared by a Flexowriter or the manufacturer's own punch. Capacity is six decimal digits per axis with accuracy to 0.001 in. and repeatability to 0.0002 in. Maximum traverse rate is 150 in. per min.–Carlton Controls Corp., Worcester, Mass.

Circle No. 363 on reply card



CONTROLS COMPUTERS

The transistorized ADRAC–Automatic Digital Recording And Control system–is specifically designed to monitor and control up to 10 analog computers of 10,000 inputs each. It can also be used, though, wherever data logging, reduction, and control are required, such as in process operations. When used in analog computing, ADRAC speeds or eliminates problem setup or checkout. Via punched tape it selects a computer, places it in an operating mode, sets the computer elements like potentiometers with an accuracy of ±0.01 percent, reads back the voltage variables to check computer element settings, and then initiates solution.–Computer Systems, Inc., Monmouth Junction, N. J.

Circle No. 364 on reply card

LOW COST, FLEXIBLE

Production accuracy to within ±0.0002 in. on a 40-in. worktable is possible with a newly announced numerical control system. The system also features low cost and flexibility achieved by modular design. Rapid change of units can be easily accomplished by a plant technician. Accuracy is obtained by separating the actuation system from the measuring system.–Diehl Mfg. Co., Subsidiary of The Singer Mfg. Co., Somerville, N. J.

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COMING NEXT MONTH

- **PNPN Switches—Diodes and Triodes**
  All you need to know about the most important semiconductor switching device.
- **Mechanizing the Adaptive Principle**
  This second of three articles describes seven systems that have been called adaptive.
- **Compensating Dc Motors for Fast Response**
  Simple check helps control engineers decide when to use compensated servomotors.
- **Computers Unfold Secrets of Human Behavior**
  Computers process experimental operant behavior data for psychopharmacologists.
- **Emergency Air Needs for Process Instruments**
  Nomograph quickly gives required emergency capacity of instrument air receivers.
- **Stabilizing On-Off Pneumatic Controls**
  Two-deadband control valve and rate feedback provides stable nonlinear pneumatic system.
- **Innovations in Numerical Control**
  Design highlights of four novel and new machine tool numerical control systems.

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falling off a log

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Frequently we have found that such problems can be anticipated and thereby overcome by a ridiculously simple dodge. Consider the relay as three devices: (a) a motor, (b) a switch, and (c) something that may have to work extra fast, extra certainly or extra something else amid the 100 g's, heat, dust, blood, sweat and 100 hours of salt spray tears present in both birds and barroom juke boxes.

With the problem thus neatly parceled out, you then consider whether you have an on-off, sliding current or single pulse signal for the "motor" to respond to; a resistive, inductive, horsepower or dry circuit load to hang across the switch, and for how long and how often this load will want to be turned on or off; and what sort of surroundings the relay will *actually* have, and whether all the taxpayers or just one 25¢ customer will suffer if the relay doesn't operate. There are other considerations such as size and cost, which you'll have to face eventually, but it's usually best to get a, b and c straightened out first.

If it turns out that the motor, switch and environmental immunities you have to have just don't exist in a single relay, either you'll have to change something or use more than one relay — or talk somebody into building you a special relay. You can do one other thing: call up one of Sigma's application engineers and tell him your troubles.

He has all sorts of answers, is anxious to have you buy some relays (Sigma) that will work for *you*, and has the advantage of doing nothing but wrestling with application problems all day long. You'll have to answer a lot of questions, but that's part of the game. We can also send you technical dope sheets on various application considerations, if you'll tell us what you particularly want to know. It's surprising how well even a relay will behave, once it's applied with your eyes open. This is one important aspect of reliability that may be lost in the statistical jungle.

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69 Pearl Street, So. Braintree 85, Mass.

AN AFFILIATE OF THE FISHER-PIERCE CO.

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PYRO-EYE*
Two-Color Optical Pyrometer

provides

fully automatic temperature measurement, recording and control in the ranges from 750°C to 2500°C and 1400°F to 4500°F.

Pyro-Eye is designed for in-plant and laboratory temperature measurement of incandescent molten metal, glass, ceramics, billets, rods, sheets, refractories and many other high temperature applications.

Continuous, automatic measurement and control of high temperatures is now possible because Pyro-Eye provides a high degree of repeatability and accuracy.

Pyro-Eye is accurate because it is relatively unaffected by unknown or variable emissivity. It measures temperature as a function of spectral characteristics . . . not as a function of total radiation.

*Trade Mark of Instrument Development Laboratories, Inc.

Get full details . . .
See PYRO-EYE in Booth 1603
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or write

IDL

INSTRUMENT DEVELOPMENT LABORATORIES, INC.
Subsidiary of ROYAL McBEE
67 MECHANIC STREET, ATTLEBORO, MASS., U. S. A.

252 CIRCLE 252 ON READER SERVICE CARD

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CONTROL BITS

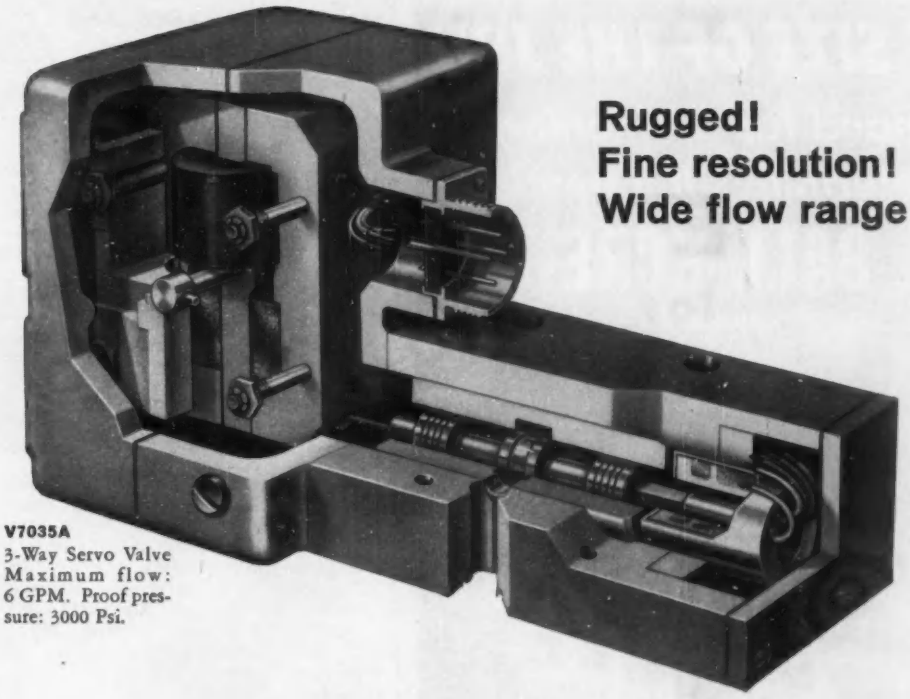
National Aeronautics and Space Administration is negotiating for a 1-kw electric arc jet rocket engine with the Plasmadyne Corp. of Santa Ana, Calif., whose proposal was chosen from among 11 submitted to NASA. In this type of rocket, capable of low level thrusts primarily for attitude control, propellant passes through an electric arc, is heated to several thousand deg F and then expanded through a rocket nozzle. The Plasmadyne engine is to be completed in 12 months, will have a minimum thrust level of 0.01 lb.

•

New entry in the optical reading machine field is Philco Corp. which has won a contract to develop an all-electronic alphanumeric recognition device for the U. S. Post Office Dept. The system is to read envelope addresses by separate recognition of the 26 letters in the alphabet and 10 numerals— without the use of special symbols or magnetic ink. Electronic scanning techniques will be employed to locate the addresses on the envelope. Identification rate Philco will shoot for: 1,000 alphanumeric characters per sec.

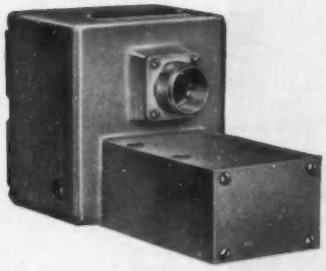
•

New measurement and control system to pulse nuclear reactors has been developed by General Dynamics' General Atomic Div. Primarily for research reactors, the new control produces a peak power level of over 1,000,000 Kw for a fraction of a second. Possible applications: industrial radiography or medical theropathy where intense sources of radiation are needed for short periods.

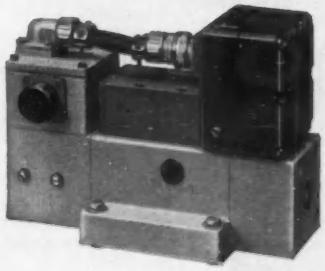


Rugged!
Fine resolution!
Wide flow range!

V7035A
3-Way Servo Valve
Maximum flow: 6 GPM. Proof pressure: 3000 Psi.



V7037B
4-Way Servo Valve
Maximum flow: 4 gallons/minute at 1000 Psi. Proof pressure: 3000 Psi.



V7040A
2-Stage Servo Valve
Maximum flow: 40 gallons/minute at 1000 Psi. Proof pressure: 3000 Psi.

VJ307A
2-Stage Servo Valve
Maximum flow: 15 gallons/minute at 1000 Psi. Proof pressure: 3000 Psi.

Honeywell SERVO VALVES

Now Honeywell offers you a complete line of electro-hydraulic servo valves designed to meet any industrial application, built to withstand all industrial environments.

Honeywell Servo Valves feature integral LVDT electrical feedback to give you the widest spring-rate selection available. Their new rate action assures greater inner-loop stability. They have a low hysteresis, low threshold, high speed of response and almost infinite resolution. They are torque actuated and can be mounted in any position. And, they have *only one moving* part so that maintenance is practically eliminated.

Used with Honeywell amplifiers, commands, feedbacks, actuators and other complementary equipment in an all-Honeywell electro-hydraulic servo system, Honeywell Servo Valves provide the most dependable, efficient machine control possible.

For complete information about Honeywell Servo Valves, call your local Honeywell office. Or write Honeywell, Dept. CE-9-87, Minneapolis 8, Minnesota.

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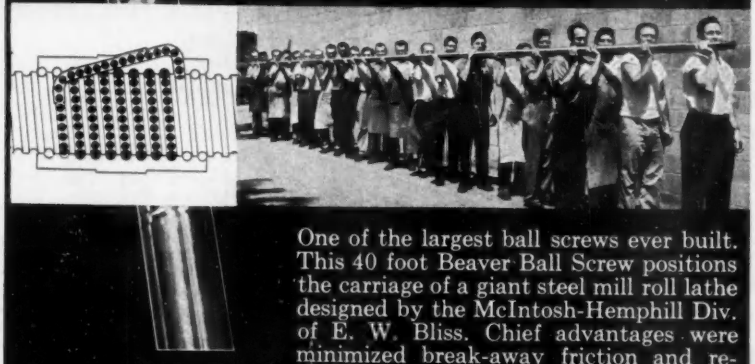
CIRCLE 253 ON READER SERVICE CARD 253

NOT THE SIZE OF THE JOB

but the demand for positioning accuracy determines the need for

BEAVER BALL SCREWS

Raytheon uses this Beaver Ball Screw in the "Hustler" search radar to actuate a delicate and extremely precise instrument control — everything else is classified, except that you can hold it between two fingers!



One of the largest ball screws ever built. This 40 foot Beaver Ball Screw positions the carriage of a giant steel mill roll lathe designed by the McIntosh-Hemphill Div. of E. W. Bliss. Chief advantages were minimized break-away friction and reduced power.

Our engineers will be glad to work with you in determining if ball screw actuation belongs in your product as opposed to hydraulics or pneumatics. Call on us.

Largest manufacturers of precision ball screws

Beaver Precision Products INC.

CLAWSON, MICH.

BULLETINS AND CATALOGS

(400) THERMISTOR CELLS. Servo Corp. of America. Technical bulletin TB 1300-6, 4 pp. Covers three new models in the Servotherm line of thermistor heat detector cells. Drawings provide cell dimensions and show internal cell construction.

(401) IR REFERENCE SOURCES. Barnes Engineering Co. Infrared bulletin 11-010, 8 pp. Provides a comprehensive outline of the historical development and scientific principles of "black body" infrared radiators. Also contains detailed descriptions, photos, and specifications covering the complete line of Barnes infrared sources.

(402) TRANSISTOR SPECS. General Electric Co. Specification sheets ECG-493, 494, 501, 502, 14 pp. total. Includes both new and revised models in the company's extensive line of NPN computer and industrial transistors.

(403) TEMPERATURE REGULATORS. OPW-Jordan. Catalog J180-1, 8 pp. Information on the company's complete line of sliding gate temperature regulators. Includes operating details, design features, and application notes. Sectional drawings illustrate details.

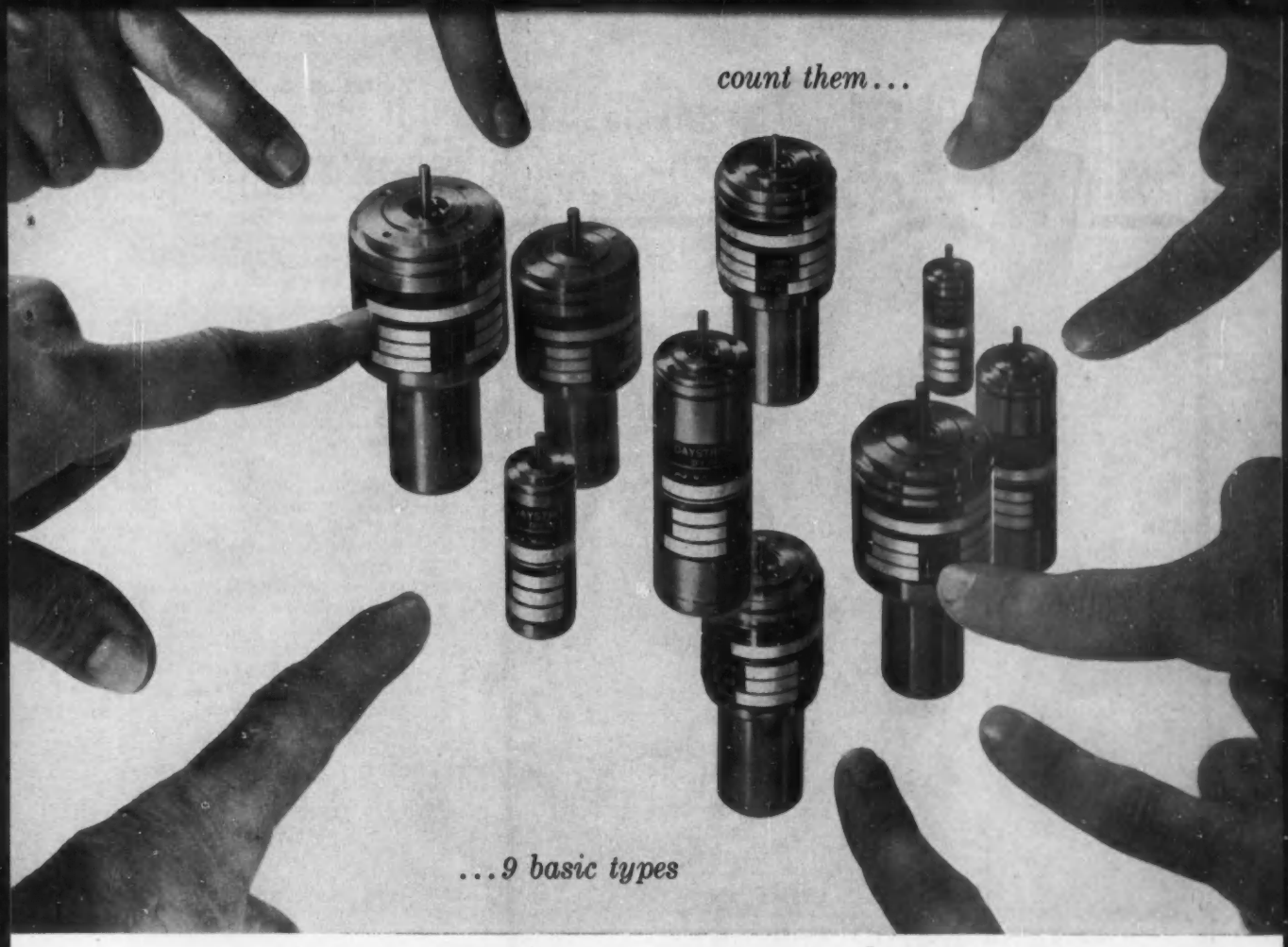
(404) DATA HANDLERS. Gilmore Industries, Inc. Bulletin G-101, 8 pp. Briefly notes the range and application of the company's packaged systems. These include: thrust, weight, and force measuring systems; digital indicating, printing recording instruments; multi-record autographic plotters; electric weighing systems; and data loggers.

(405) TANTALUM CAPACITORS. Fansteel Metallurgical Corp. Bulletin 6.100-5, 14 pp. Handy booklet provides the most complete and latest technical information on wet-type tantalum capacitors. Designed to give the electronics engineer all the information he needs for military or industrial applications, bulletin contains specification tables, performance curves, and application data.

(406) COMPUTER APPLICATIONS. Computer Systems, Inc. Technical report, 16 pp. Entitled "Mathematical Applications of the Dynamic Storage Analog Computer", this paper discusses such applications as sequential calculations through time sharing of computer elements; use of memory to obtain definite integrals for automated, self-solution of optimization problems; solution of multiple integration problems by a combination of repetitive and real-time operations together with continuous or point memories; and the solution of partial differential equations.

(407) MAGNETIC HEADS. Minneapolis-Honeywell Regulator Co. Specifications DS 330a, 6 pp., and DS 3400, 2 pp. First bulletin provides complete specifications on recording and reproducing heads; second bulletin lists specs on three representative types of Honeywell drum heads.

(408) AIR CONTROL VALVES. Hoffman-Odom Co. Catalog, 40 pp. Covers in-line two, three, and four-way valves; sub-base mounted four-way; and four-way five-



temperature-compensated motor-tachometers

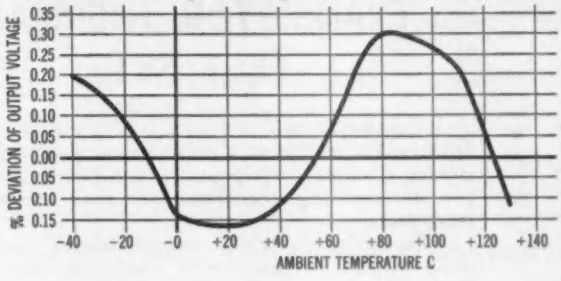
Only at Daystrom's Transicoil Division can you find such a splendid array of temperature compensated high-accuracy motor-tachometers.

Here's the lineup:

4- and 6-pole in Sizes 8 and 11; 4- and 8-pole in Sizes 15 and 18; and a special high-torque 4-pole model in Size 18. But this is only the beginning—it doesn't include all the variations in motor windings and shaft configurations that we can conjure up to meet unusual requirements.

And what about performance? Let us merely assure you that these are the most temperature stable servo components of their kind we've ever had the opportunity to test.

Deviation of Output Voltage vs. Ambient Temperature



Ask to see our specification sheets and then discuss your needs with Daystrom's Transicoil Division.

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CIRCLE 255 ON READER SERVICE CARD

For SIMPLIFIED TRANSISTOR and DIODE TEMPERATURE MEASUREMENTS

THE NEW RESCON TRANSISTOR THERMAL TEST SET

This single, self-contained unit provides complete facilities for temperature measurement problems in designing electronics equipment. It is especially applicable for determining transistor junction temperature measurements.

Determination of heat sink efficiencies, temperature rises, thermal environmental conditions, location of "hot spots", heat transfer efficiency of transistor mounts, and thermal gradients of the overall equipment are just a few of the unlimited applications.

The Thermal Test Set is easy to use — all readings are accurate and *direct* — no batteries, power compensations, calibrations or complex instructions required. Rugged construction for long-term service.

RESCON
ELECTRONICS CORPORATION
151 Bear Hill Road, Waltham 54, Massachusetts

port valves. These include valves that are air operated, solenoid pilot operated, as well as valves having a solenoid pilot with booster or a double solenoid pilot. Features include valve selection tables, parts tables, and cutaway drawings.

(409) LVDT AUXILIARIES. Schaevitz Engineering. Catalog SE-60-2, 4 pp. Illustrates and describes a line of instruments designed for use with linear variable differential transformers in measuring, indicating, recording, and control systems. Instruments include an extended scale indicator, recorders, transformer and bridge demodulators, a servoamplifier, a micrometer test stand, a reference transformer, and a line of filters.

(410) PRESSURE PICK-UP. Consolidated Electrodynamics Corp. Bulletin 4382, 2 pp. Offers details on a new Type 4-382 potentiometer pressure transducer, a lightweight instrument designed for missile and aircraft applications in low presure ranges. Illustrations include photo and dimension drawings.

(411) INDUSTRIAL AUTOMATION. General Electric Co. Bulletin GED-3908, 16 pp. Assesses the current state of the automation art, summarizes the need for economic benefits of automation, provides information for management on six key functions of automation: process control, computing, instrumentation, numerical control of machines, sensing, and the field of communications.

(412) MAGNETIC PARTICLE CLUTCHES. Lear, Inc. Brochure, 16 pp. Describes characteristics of magnetic particle clutches ranging in capacity from 2.5 oz-in. to 1,900 lb-in. Curves, installation drawings, and other illustrations are used to acquaint design engineers with 10 different series of clutches and their possible uses.

(413) INDUSTRIAL TELEMETERING. Electro-Mechanical Research, Inc. Brochure, 8 pp. Pictures simplify description of the ASCOP industrial telemetering equipment and how it works. Also outlines typical systems and provides detailed specifications.

(414) SMALLEST 115-VOLT SERVOMOTOR. Helipot Div. of Beckman Instruments, Inc. Data sheet No. 60250, 4 pp. Contains advanced performance data on a new Size 8 servomotor wound for 115-volt operation. In addition to dimensional outline drawings and torque-speed characteristic curves, bulletin notes construction details and spells out all principal characteristics.

(415) CLUTCHES & DIFFERENTIALS. Sterling Precision Corp. Catalog No. 63, 48 pp. Offered as a supplement to Sterling's general catalog, this booklet presents a complete stock line of miniature magnetic clutches, brakes, and precision differentials.

(416) TRANSFORMER DATA. Triad Transformer Corp. Bulletin TY-61. Provides complete electrical and mechanical specifications on all units of Triad's transistor transformer line, including resistance and capacitance values for all circuits. Also shows wiring diagrams and schematics and

This desk size **160 COMPUTER** (for only $60,000 basic cost) will solve hundreds of engineering and scientific problems at speeds greater than many large-scale computers in use today

COMPARE THESE FACTS

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BASIC CYCLE TIME — 6.4 millionths of a second
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AVG. EXECUTION TIME — 15.0 millionths of a second
INFORMATION READ AVAILABLE AFTER START OF CYCLE — 2.2 millionths of a second

160 EXECUTION SPEEDS OF TYPICAL SUBROUTINES

Performs 22-bit addition in 185 millionths of a second

Performs multiplication with 22-bit product in 1 thousandths of a second

Performs sine of X, through X $\frac{11}{11}$ quadruple precision, avg. computation, one value, in 190 thousandths of a second

Sorts 10,000 80-character records in 18 minutes

BASIC FACTS Low cost ($60,000 purchase price — lease policy also available) • All transistorized 5 megacycle circuitry • Magnetic core storage • Non-volatile memory • 63 instructions • Complete programming package • Complete line of peripheral equipment • High reliability, low power consumption (500 watts) • Operator display panel where programs can be, if desired, loaded manually

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Director of Sales
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CIRCLE 257 ON READER SERVICE CARD 257

This is one of the many applications for the Stepper Motor — a device for translating electrical pulses into accurate, bi-directional, incremental shaft displacements.

The Synchro Positioner uses two Stepping Motors, an Autosyn differential, and a built-in pulse generator. One motor positions the Autosyn Shaft in coarse increments in either direction, while the other motor, using a different gear ratio, positions the same shaft in vernier increments in either direction. As the reset command signal is of steady-state type, the built-in pulse generator permits use of the driving motors for the reset function.

STEPPER MOTORS CORPORATION

Subsidiary of California Eastern Aviation, Inc.

7442 West Wilson Avenue • Chicago 31, Illinois

258 CIRCLE 258 ON READER SERVICE CARD

Bulletins & Catalogs

lists typical transistors and rectifiers for each transformer.

(417) HIGH TEMP MOTOR. Airborne Accessories Corp. Product Bulletin PS-8A, 4 pp. Describes the company's HM-420, a high temperature ac motor having a working ambient temperature range of from −65 to +600 deg F. Contains a photo of the motor along with performance curves, outline drawings, general engineering data, and a section on special design features.

(418) THERMOCOUPLE ASSEMBLIES. Conax Corp. Catalog 1890, 32 pp. Superseding catalog 1885, this catalog fully illustrates and describes a complete line of thermocouple fittings, pressure sealing glands, and thermocouple accessories.

(419) RECORDING OSCILLOGRAPH. Consolidated Electrodynamics Corp. Bulletin 1623A, 8 pp. Contains a detailed description of CEC's Type 5-123 recording oscillograph, using photos and drawings to illustrate special optical, mechanical, electrical, and physical specifications.

(420) THERMISTOR MANUAL. Fenwal Electronics, Inc. Bulletin DMC-3, 24 pp. Describes what thermistors are and what they do, gives several examples of how they are used, tells how to solve thermistor problems, and contains a list of aids that have been developed specifically for such problems.

(421) MOISTURE MEASUREMENT. Henry Francis Parks Laboratory. Bulletin, 4 pp. Interesting discussion on moisture measuring techniques and the reasons behind the company's selection of a particular type of moisture gage.

(422) ADJUSTABLE TIME DELAYS. G-V Controls, Inc. Technical Publication No. 80, 4 pp. Contains dimensional drawings, typical performance curves, and complete specifications covering two types of general purpose transistorized time delay relays with delays of from 0.1 to 300 sec.

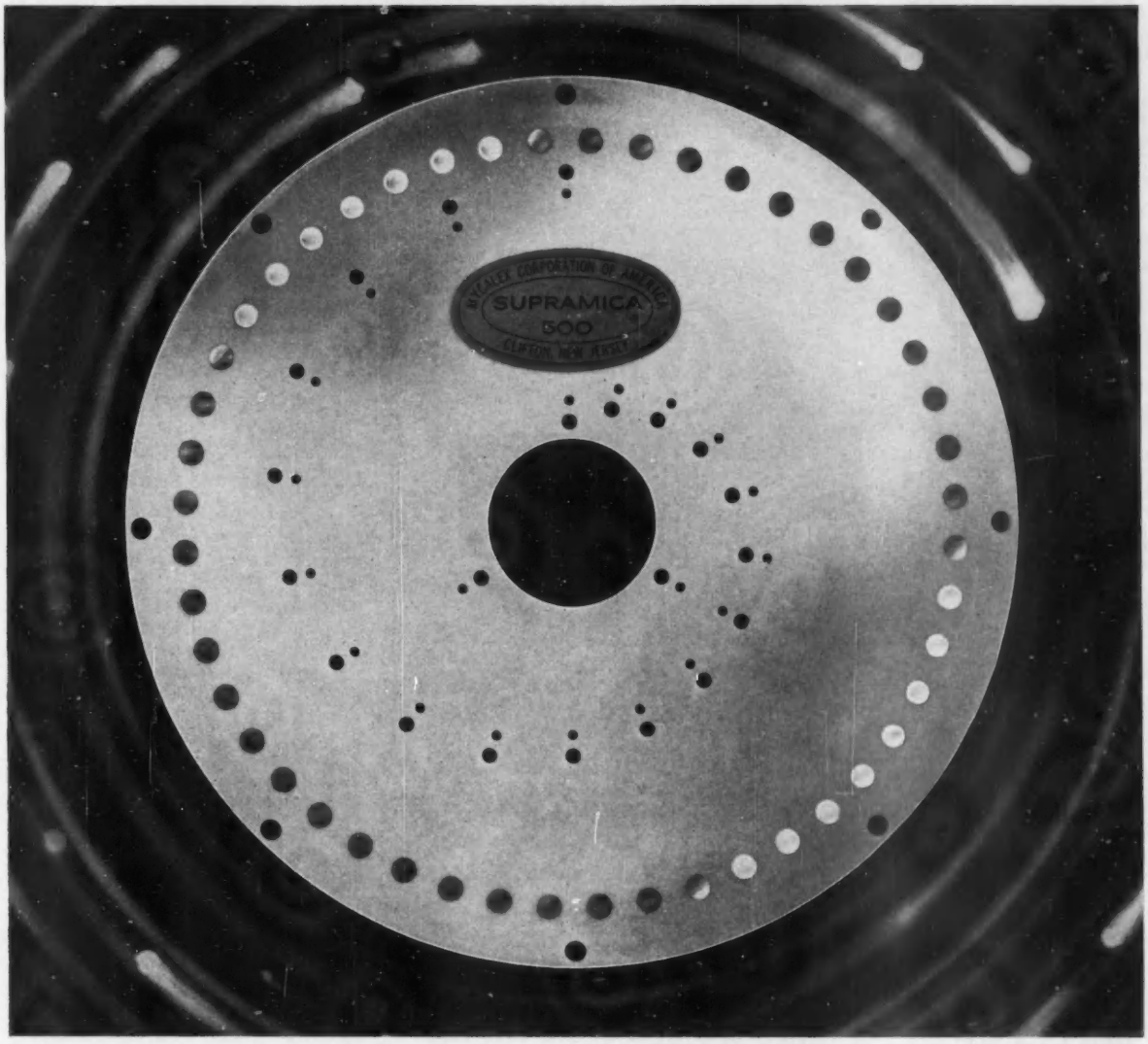
(423) PRESSURE TRANSMITTER. Conoflow Corp. Bulletin P-36-1, 2 pp. Presents details on the design, operation, and application of the Model P pressure and liquid level transmitter. Photos, sectional drawings, and schematics illustrate the text.

(424) FAST TAPE PERFORATOR. Soroban Engineering Co. Booklet, 20 pp. Describes the mechanical components, circuit design considerations, operating theory, and complete performance characteristics of the company's Model GP-2 Super-Speed tape perforator.

(425) MOTOR-TACH GENERATOR. John Oster Manufacturing Co. Data Sheet 6252-03, 2 pp. Deals with a new Size 11 combined motor-tach generator unit. Details include complete performance specifications on both elements as well as mechanical and physical characteristics.

(426) INDUSTRIAL MEMORY SYSTEM. Republic Electric & Development Co. Brochure, 4 pp. Provides complete information on the Magnestat memory system, a system built around a magnetic memory disc and designed for a wide range of industrial applications in handling, marking, sorting, or conveying equipment.

When the requirements seem impossible...



48 precious metal contacts on a 12" circle... maintaining .0003 T.I.R. planar tolerance

To SEE under the sea takes a scanning commutator with seemingly impossible tolerances to insure reliability in ship sonar. That is why compression-molded SUPRAMICA® 500 ceramoplastic machinable insulation was chosen . . . a proud example of MYCALEX CORPORATION OF AMERICA craftsmanship.

The specifications are most demanding, the requirements highly critical . . . plates must be flat within .0003" and embody precision-machined recesses to accept 48 pure silver contacts. The angular displacement of the contacts is held to ±1 minute. The combination of contacts and SUPRAMICA 500 together must accept a 2 micro inch surface finish. The application requires that these tolerances are guaranteed for the life of the commutator during which the environmental conditions run the gamut of humidity and temperature.

The MYCALEX fabricating facility is not only fully qualified to furnish the fabrication of such parts but will design and provide required hardware. For gauge-like specifications on large production runs or short prototype quantities . . . our engineers are ready, capable, and equipped to assist you with your design and production requirements. Write for information on SUPRAMICA ceramoplastics offering maximum temperature endurance (unstressed) up to +1550°F. and SYNTHAMICA® synthetic mica with maximum temperature endurance (unstressed) up to +2000°F. . . . the family of the world's most nearly perfect insulation materials.

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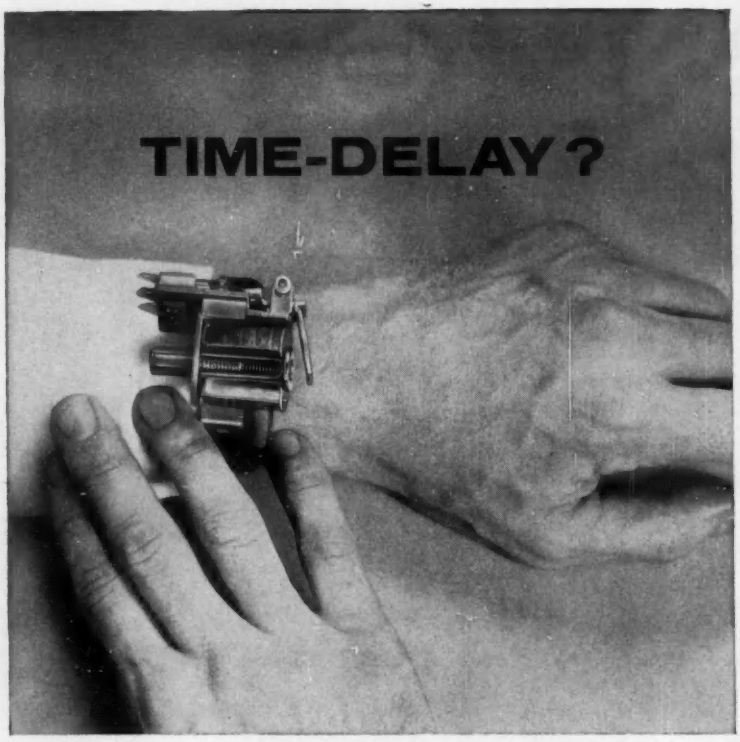
World's largest manufacturer of ceramoplastics, glass-bonded mica and synthetic mica products



Heinemann can give you any set delay from a quarter-second wink to a two-minute yawn, all wrapped up in a relay no bigger than a healthy ice cube. Called the Type A Silic-O-Netic Relay, this three-ounce time-delay unit offers S.P.D.T. or D.P.D.T. switching, with up to three amps' contact capacity. All of which is pretty good, but the real clincher is the continuous-duty coil. It permits the relay to be energized continuously, to serve as a load relay, too. This eliminates the need for auxiliary lock-in circuits. Result: substantial savings in space, wire, solder—and dollars. Bulletin 5003 gives detailed specifications; a copy is yours, of course, for the asking.

HEINEMANN ELECTRIC COMPANY

156 PLUM STREET TRENTON 2, NEW JERSEY

2175

WHAT'S NEW

(Continued from page 56)

control maker, have been combined in a new Systems and Controls Group to promote interchange of ideas and permit integration of individual components in complete systems.

Included in the group are Hydro-Aire Co., Burbank, Calif.; Chapman Valve Manufacturing Co., Indian Orchard, Mass.; and Swartwout Co., Hooksett, N. H. Hydro-Aire specializes in hydraulic, pneumatic, and electronic controls; Swartwout was a pace-setting originator of electronic controls; Chapman makes valving.

British Instrument Dilemma: Did the Moscow Show Pay Off?

MOSCOW—

British instrument manufacturers can't be sure yet just how well aggressive sales efforts in the Soviet bloc will pay off. Acting under the auspices of Britain's Scientific Instrument Manufacturers Association, 41 firms put on an exhibition of their wares in Moscow's Polytechnic Museum June 18-29 (reported in CtE, Jan. '60, p. 57). Results of the show: $616,000 worth of instruments were sold.

But when this $616,000 is divided up by the 41 companies—after subtracting $101,600, the largest single sale, an Elliott 803 computer—and allowing for the show's expense averaging $8,400 apiece, it's hard to say whether the trip was worth it or not.

• **British think so**—Some SIMA members think so. One comment on the show's worth came from Manager Woodhead of Cossor Instruments Ltd.: "We have sold everything on the stand we wanted to sell." In fact, 95 percent of all the instruments in the show were sold on the spot.

There was interest aplenty among the more than 5,000 "interested" visitors. Tons of literature, prepared in Russian, disappeared almost as fast as it could be handed out. But part of the problem of doing business with the Russians is finding the key people. One spokesman explained the problem: "Obviously not all the visitors were people we really wanted to reach. Many of them were students or young technicians out to learn what they could. But one can't afford to refuse literature to anyone—he may be connected with an important institute.

• **Sell the user**—Behind the show was British feelings that contacts with the huge, cumbersome Soviet trading organizations like Mashpriborentorg (the machine instrument trade bureau) are

MECHATROL ROTATING COMPONENTS

Whatever the particular application for precision rotating components, you can depend on **Mechatrol's** versatile Engineering and Production experience to resolve the problem of supplying the right motor to meet your requirements, either during the initial design stage or the production phase. **Mechatrol** is always ready to lend assistance, whether the need be for a standard type of unit or one that meets the exacting environmental requirements for advance types of missiles, space vehicles, undersea or airborne crafts. **Mechatrol's** components are offered in a wide variety of frame sizes ranging in diameter from 1/2 inch to 2 inches. These include servo and synchronous types with or without integral gearheads, viscous and inertially damped servo motors, miniaturized damping tachometers and temperature compensated integrating tachometers. High performance components delivered on schedule to meet every requirement.

We would be pleased to send you our new motor catalog RC 600 which provides complete technical data on precision rotating components. Please submit requests on your company letterhead.

MECHATROL DIVISION

SM/I

SERVOMECHANISMS/INC.

1200 Prospect Avenue, Westbury, L. I. New York

Mechatrol of California, 12500 Aviation Blvd., Hawthorne, Calif.

CIRCLE 261 ON READER SERVICE CARD 261

MASSA
RECORDING SYSTEMS

ZERO BASED LINEARITY 1/4 MM
(40mm FULL SCALE)

The lightweight, high-speed oscillograph Model OS-600 shown at the right is provided with INDIVIDUAL LINEARITY CONTROL ADJUSTMENTS for precisely setting the linearity at both extremes of deflections. This feature completely eliminates all errors due to inherent production variations in spring stiffness and magnetic field distribution near full scale amplitudes.

This rugged oscillograph, THE ONLY SOURCE FOR DIRECT RECTILINEAR INK WRITING, accurately records signals from DC to 120 cps. The electrodynamic drive system produces true rectilinear displacement of the pen tip. Electric writing can be effected by merely substituting an electric stylus for the ink pen.

LINEARITY CONTROL ADJUSTMENTS

PORTABLE AND MULTICHANNEL SYSTEMS

Available in 20 mm amplitude for rise time resolution of a few milliseconds, and 40 mm amplitudes. Individual transistorized driver amplifiers and power supplies for each channel designed to operate with frequency compensation either in or out.

MORE DATA
PER DOLLAR

PREAMPLIFIERS

A wide choice of plug-in preamplifiers is available to satisfy every recording requirement: low, medium, and high gain chopper DC, universal carrier and phase sensitive demodulator. Zero suppression is available on most models.

WESCON Booth Nos. 557-558

OTHER MASSA PRODUCTS
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TRANSDUCERS — HYDROPHONES
AMPLIFIERS
COMPLETE LINE OF MULTI-CHANNEL AND PORTABLE RECORDING SYSTEMS

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262 CIRCLE 262 ON READER SERVICE CARD

WHAT'S NEW

Russians huddle with a salesman at the British instrument show held in Moscow's Polytechnic Museum. On-the-spot sales were just $616,000, but the British hope there's more to come.

not enough. Reaching the end users will create a demand which will be reflected in the purchasing trusts.

The British found that sales went in three stages. First, interested customers (laboratories, institutes, industries) would express an oral desire to buy, but they lacked the authority. Next came negotiations with Mashpriborentorg, which eventually would give an oral "yes" or "no." Last came the written contract. However, "when Mashpriborentorg says you're in," said one firm's salesman, "you can be pretty sure you're in."

The English squashed reports of tough bargaining sessions with the Russians, insisted that they were getting normal prices for their wares—except that they gave a discount in the form of free freight from England.

On display was a wide assortment of instruments — mostly electronic. Gear exhibited: frequency regulators, industrial TV equipment, infrared spectrometers, analog to digital converters, computers, etc.

Roughly a third of SIMA members showed up; companies included Hilger and Watts, Cambridge Instrument, Marconi Instruments, Avco Ltd., Mullard, and EMI, to mention only a few. The exhibition was set to coincide with the International Federation of Automatic Control Congress (see CtE, Aug. '60, p. 24) which opened June 27.

One exhibitor was approached repeatedly for the schematic diagram of an analog to digital converter—with no assurance that the apparatus would eventually be purchased. (It wasn't.) It pointed up another problem of doing business with the Russians: protecting patent rights.

• **For copying purposes?**—For the most part the British realize the Soviet posi-

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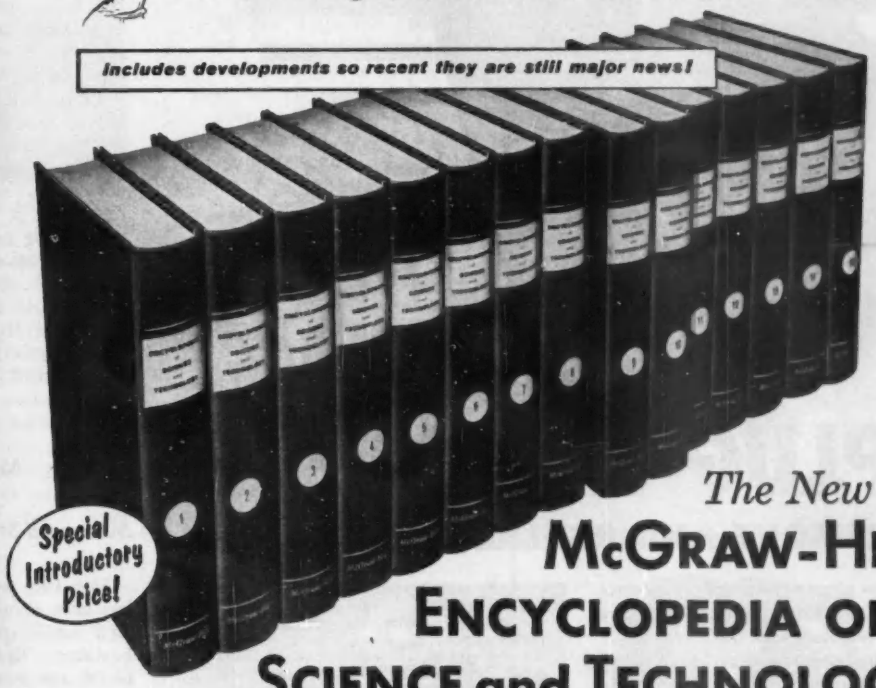

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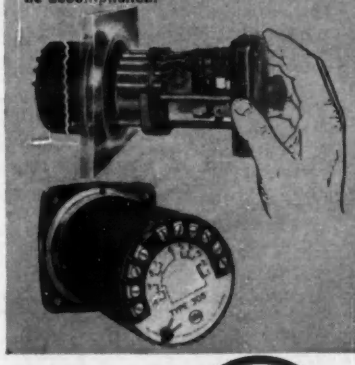
WHEN INSTALLED, the plug-in model's plated, non-corrosive hex sockets engage plated banana plugs in a tubular case for positive spring pressure contact. A keyed guide pin aligns timer in its tubular enclosure, protrudes through rear to accept a snap-in cotter pin clip, assuring continuous full-contact engagement. This safety clip must be removed before unplugging a "hot" timer, so that only authorized persons can make timer replacements. An optional front-mounting clamp is available for installation where rear accessibility cannot be accomplished.



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tion on patents is "obscure". But they are willing to turn their heads for two reasons: first, there have been many repeat instrument orders placed by the Russians in the past, and second, instrument sales volume in the USSR is "very large indeed and has been growing in the last few years".

One exhibitor, Twentieth Century Electronics, was sounded out on granting the Soviets licenses for manufacture of its neutron counters and other devices, but reportedly insisted on outright sales in view of the difficulty of monitoring output volume in Russia.

Future sales seemed to be the key to the British optimism. Elliott Brothers, for example, received indications that orders for 10 more computers might be forthcoming. And other companies, though most realized a profit from on-the-spot sales, were waiting to see what was to come.

—Ernest Conine
McGraw-Hill World News

Motorola Steps into Control

PHOENIX, ARIZ—

For the past two years Motorola has been shopping to buy a company that would put it into the control business. But somehow Motorola could never find just the right organization. Last month the builder of home and car entertainment appliances, semiconductor devices, and microwave equipment solved the problem itself. Assembling a nucleus of well known control men and banking on its recently established reputation for solid state electronics, Motorola formed a Solid State Control Dept., Dr. D. E. Noble, a company vice-president, told CtE.

The new group is spawned from the company's Communications, Semiconductor, and Military Electronics Divs. located near Phoenix. To augment the company's own capabilities in the field, Motorola has added some outside technical talent.

Two top executives in the new department are Kenyon and Charles Swartwout, who had previously built the Swartwout Co. into a pioneer in the electronic process control field before selling the controls division to the Crane Co. (CtE, Feb. '60, p. 42). Another control newcomer to Motorola is Oliver H. Mackley, who started the Ohmac Co. of Phoenix to supply control equipment to the utility industry after spending 17 years with RCA and serving a stint as vice-president and general manager of Hycon Electronic Test Equipment Div.

Dr. H. William Welch, Jr., Mili-

Dr. H. W. Welch, Jr., Kenyon Swarthout, and Dr. D. E. Noble inspect a piece of Motorola automatic checkout gear that will form a springboard for the firm's jump into control systems.

tary Div. R & D head and general manager of the Solid State Electronics Dept., has been picked to head the controls unit. Dr. Welch has scheduled product planning and development as major activities for the coming year; then production of a comprehensive line of industrial control and instrumentation equipment will begin as Motorola bids for a major share of the market.

Motorola plans the department as the somewhat polygamous marriage of several skills already demonstrated within the company and without. The Swartwouts are expected to supply the process control experience. Dr. A. L. Alden, manager of operations for the Solid State Electronics Dept., will help apply the company's know-how in electronic ceramics research, solid state integrated circuitry, and ferrite and thin film magnetic logic and digital circuitry. Mackley's Ohmac Co. had developed a data link power exchange computer billing system which was well received by power, gas, and irrigation industries in the southwest.

The systems touch will be lent by Leslie Norde, formerly chief engineer in the Military Electronics Div.'s Data Systems Lab. He'll be expected to draw on Motorola's experience in industrial supervisory control equipment (a product of the Communications Div.) and in transistorized automatic test equipment.

Starling Corp. is New Firm In Medical Instrumentation

Newly created in W. Los Angeles is the Starling Corp. which will produce a line of precision medical instruments. President of the new firm is Louis Fields, who is chief engineer of Pacific Technical Co., the research companion company to Starling, and also consultant in medical instrumentation at UCLA.

Primary product of the company

TIMERS

Atcotrol Transistor Timers excel for short interval highly repetitive timing cycles. Conservatively rated at 3 million operations. Six timing ranges 1.5 seconds to 150 seconds. Rated 15 amps @ 115 VAC, 10 amps @ 230 VAC, 4 amps @ 115 VDC. **Series 308**

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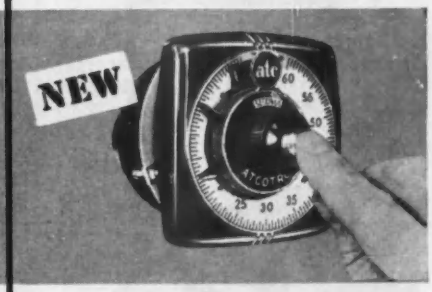

Atcotrol "Duo-Set" Timers control two independently adjusted load circuits for on-off cycling. Set desired delay between deenergizing of forward and energizing of reverse. End interrupting timer motor, straining of mechanism. **Series 306**

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CIRCLE 265 ON READER SERVICE CARD 265

will be the Fox Glove system, which is an application of a digital computer designed to display items like blood pressure, temperature, and respiration of a patient undergoing surgery or under observation.

News of Other Companies In the Control Field

Tyco, Inc. is a new firm formed in Rochester, N. Y., by Dr. Arthur W. Taylor, former assistant director of research of Eastman Kodak Co. and a founder of Itek Corp. Tyco will supply capital, management and facilities in the solid state devices, energy conversion, and data processing fields.

Westinghouse Electric Corp. is establishing an Astroelectronics Laboratory in the Comejo Valley near Los Angeles. The facility is to work with the military and defense contractors on the west coast in the development of advanced electronic equipment.

Itek Corp., of Waltham, Mass., and Hermes Electronics Co. of Cambridge, Mass., have obtained stockholder approval for the merger of the companies on the basis of four shares of Hermes common for one share of Itek. No word was issued at the time by Itek president, Richard Leghorn, on a reported merger of the new organization with Chicago Aerial Industries.

The Bristol Co., a subsidiary of American Chain & Cable Co., Inc. in Waterbury, Conn., has acquired Hanson-Gorrill-Brian, Inc. of Glen Cove, N. Y. The new business will be operated through a subsidiary that has been set up under the name of The Data-Master Corp.

IMPORTANT MOVES BY KEY PEOPLE

Gisel Heads New Slate In Bell Aerosystems Setup

New president of Bell Aerosystems Co., formerly Bell Aircraft's Niagara Frontier Div., is William G. Gisel. The company is a division of Bell Aerospace Corp., Buffalo, N. Y., now a wholly owned subsidiary of Textron, Inc. Gisel was vice-president of Bell Aircraft and general manager of the Niagara Frontier Div. before it was sold to Textron.

Promoted to vice-president of avionics was John H. van Lonkhuy-

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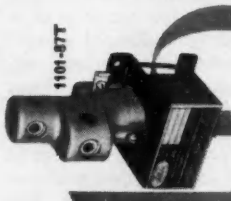

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zen, and William M. Smith was named vice-president, engineering.

Two presidents of other subsidiary companies of Bell Aerospace were also named. Bell Helicopter, Ft. Worth, Tex., will be headed by Edwin J. Ducayet, succeeding Harvey Gaylord who is now president of Bell Aerospace. Carroll M. Martenson will be president of Hydraulic Research and Manufacturing Co. in Burbank, Calif., which makes servovalves and controls.

Dr. Du Mont to Manage Labs Under Fairchild

Following the recent acquisition (CtE, May '60, p. 194) by Fairchild Camera and Instrument Corp., Syosset, N. Y., the Allen B. Du Mont Laboratories Divs., it was announced last month, will be managed by Dr. Du Mont.

As group general manager Dr. Du Mont will have the over-all responsibility for the Electronics Tubes Div. and the Industrial Electronics Div. in Clifton, N. J. Du Mont's military operations have been integrated with Fairchild's Defense Products Div.

Royal Little Moves To Expand Textron Electronics

The 64-year-old chairman of Textron, Inc., Royal Little, who has in seven years boosted the company's sales from $100 million to $308 million primarily by acquisitions, has now resigned as Textron chairman and has been elected president of the subsidiary Textron Electronics, Inc.

Little says he will apply the same acquisition technique to try to raise the electronics firm's annual sales from the current $30 million to $100 million in the space of three years. Textron Electronics, only one year old, has already accumulated seven companies. Earnings last year were $383,232 on $9.8 million sales. Textron holds 78 percent of the affiliate's stock, and Little is said to have 57,855 shares of Textron Electronics common.

Other Important Moves

Robert L. Pappas is now vice-president of Ampex Corp. in Redwood City, Calif. Pappas is manager of the Ampex Military Products Co., has been with Ampex since 1955, coming from the Schaible Co.

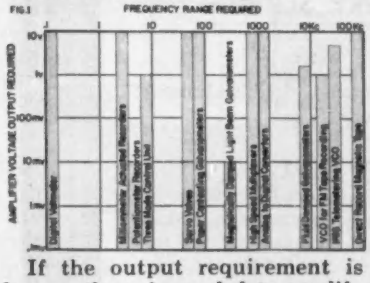
Dr. Van W. Bearinger has been named to fill the director of research

D-C AMPLIFIER EVALUATION *number 4 in a series*

AMPLIFIER GAIN

The voltage amplification or gain of a d-c amplifier is the dimensionless ratio of the output voltage to the input voltage, assuming operation in the linear portion of the amplification characteristic, and at a specified frequency, usually 0 cps. The curve of amplifier gain vs. frequency of the input signal is termed "frequency response".

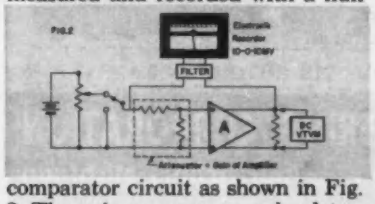
The gain factor is of little value to the user unless the minimum full scale input or the maximum linear full scale output is known. As part of a system, the desired amplifier output level is determined by the load characteristics. Typical amplifier loads are shown in Fig. 1.



If the output requirement is known, the gain needed to amplify the input to give full scale output can be determined. However, power requirements must also be considered. If the load resistance is sufficiently low the maximum output current is reached before maximum voltage output, and the amplifier will saturate with further increases in input signal. The value of the voltage across the load with maximum rated current is then used to determine gain.

Gain Stability vs. Gain Accuracy

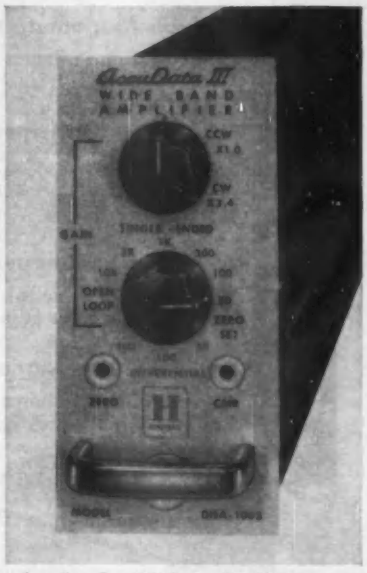
The errors in gain caused by external factors such as ambient temperature, line voltage, and component aging are termed gain instability. Gain accuracy is the allowable tolerance between gain settings and actual gain. Gain instability may be measured and recorded with a null



comparator circuit as shown in Fig. 2. The gain accuracy may be determined by substituting in this circuit a precision attenuator. For information on gain stability measurement write for application notes BEAN 122.

AccuData III has Gain of 34,000

Full scale output of the new Honeywell AccuData III d-c amplifier is 10 volts, 25 milliamps up to 20 kc. Minimum full scale input is 0.3 mv single-ended, a voltage gain of 34,000. Its gain instability is ± 0.01% for a ± 10° F. temperature range. Gain setting accuracy with the fine gain control in the CCW position is ± 0.2% for differential or single-ended connected gains up to 1000, and ± 0.5% for



gains in the 3000 to 34,000 range. Eleven different gain positions including zero and an open loop position for operational amplifier connections are provided. Other features of this amplifier include high common-mode rejection, very low noise and drift, and unparalleled linearity. Write for Bulletin BS DISA-3 to Minneapolis-Honeywell, Boston Division, Dept. 34, 40 Life St., Boston 35, Massachusetts.

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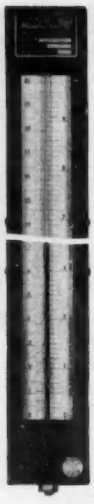


U-Type Manometers

Single cleanout (shown at right); double cleanout; with 3-valve manifold; inverted.

Well-Type Manometers

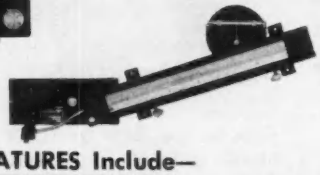
Low-well (shown at left); raised-well; adjustable-well; barometric; instrument test (8-scale); flow-meter.

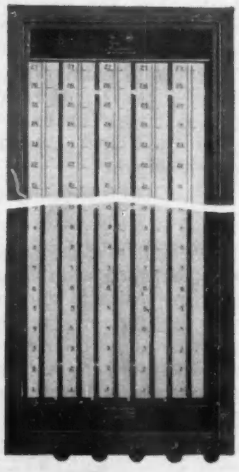
Multi-Tube Manometers

With individual wells in fixed position; with common wells, fixed or adjustable; Photo-Manometers.

Inclined-Tube Manometers

General-utility (shown below); high-precision; draft gauges.





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WHAT'S NEW

post left vacant at Minneapolis-Honeywell Regulator Co. last year when Dr. Finn J. Larson became corporate vice-president in charge of research. New assistant directors of the Research Center are Dr. John N. Dempsey and Edward E. Rexer.

William S. Aiken has been promoted to director of engineering at Thompson-Ramo-Wooldridge Products Co., Beverly Hills, Calif., from a position as manager of Project Engineering. Before joining TRWP in 1957 he was with Sperry Gyroscope.

Dr. Isidor I. Rabi, Nobel prize-winning physicist, has accepted a position as technical consultant to Loral Electronics Corp., New York.

Richard E. Horner has become senior vice-president in charge of technological matters at Northrop Corp. Horner recently resigned as associate administrator of NASA in order to accept the position with the Beverly Hills, Calif., firm.

Lawrence E. Maley is the new sales manager of Waters Associates, an analytical instrumentation manufacturer in Framingham, Mass.

Dr. Nicholas E. Golovin has been elected vice-president and general manager of the Rabinow Engineering Co., Inc., Takoma Park, Md. He assumed the post last month after serving as deputy associate administrator of NASA.

Dr. Peter Elias, 36, as been named by Massachusetts Institute of Technology as its new Dept. of Electrical Engineering head. Dr. Jerome B. Wiesner, who has been acting head of the E.E. Dept., will continue as director of MIT's Research Laboratory of Electronics and work with the Center for Communication Sciences.

Edward H. Heinemann has resigned his post as corporate vice-president of Douglas Aircraft Co. in charge of combat aircraft engineering, aircraft, and missiles to become executive vice-president of Summers Gyroscope Co. in Santa Monica, Calif.

Dr. James W. Moyer has been announced as the research director of the Sperry Rand Research Center to be built this year in Sudbury, Mass. Dr. Moyer has for the past 12 years been with GE in long range technical planning and research posts.

ABSTRACTS

Aids conversion

From "Calculator Obtaining Frequency Response From Transient Response", by Seizo Fujii. Journal of the Society of Instrument Technology, Japan, Vol. 10, No. 4, pp. 217-222. In Japanese.

When designing automatic control systems it is more advantageous to know the frequency response rather than the transient response characteristics of the controlled process. However, in the frequency response testing of processes having large time constants it is rather difficult to obtain useful information free from the influence of external disturbances which will more than likely arise during the lengthy testing time. On the other hand, transient response tests can be accomplished more quickly, but conversion of the resulting responses to the equivalent frequency response without some computing aid ordinarily takes considerable calculating effort.

For this reason a simple calculator for obtaining frequency response from transient tests was manufactured for trial. The article describes its principles and construction and gives calculation example. The accuracy is within plus or minus 3 percent in gain and within plus or minus 3 deg in phase angle for frequencies less than those which give a phase angle larger than minus 80 deg, in the case of the typical example of a single order lag process. Computing time for a particular point is about 3.5 min.

Russian readers

From "On Principles of Reading Machine Construction", by A. A. Kharkevich. Radiotekhnika, Vol. 15, No. 2, 1960, pp. 3-9. In Russian.

The paper discusses some general problems of constructing reading machines. The definition of a reading machine is given as a machine which automatically recognizes letters, digits, and other signs of a printed or written text. Any reading machine has to perform the following basic operations: presentation and examination, preparation of description, and comparison of the description with a standard, proper recognition operation.

The examination consists of the action of the presented pattern on a transducer, normally of the photoelectric type, whereby a electrical signal is produced. The description is the most important operation. It consists of

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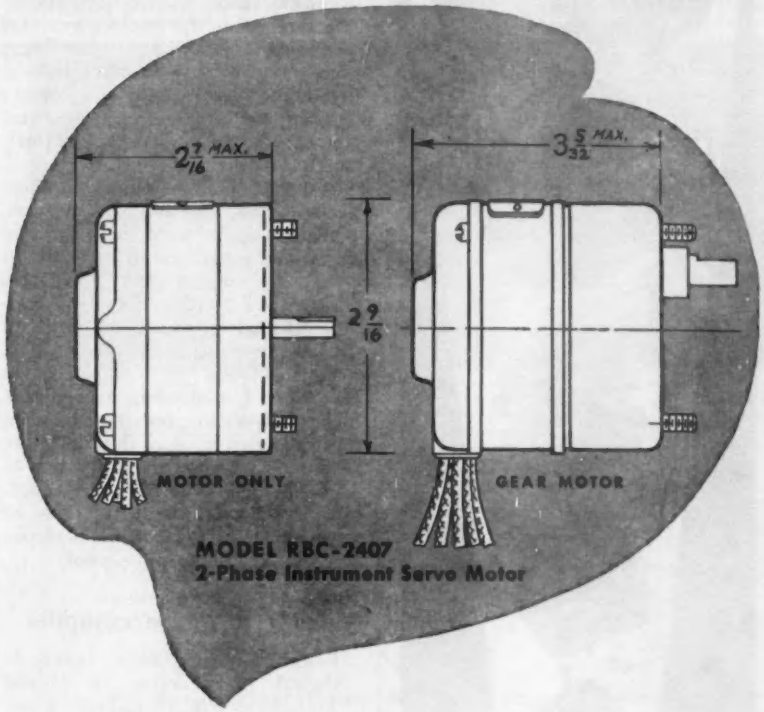

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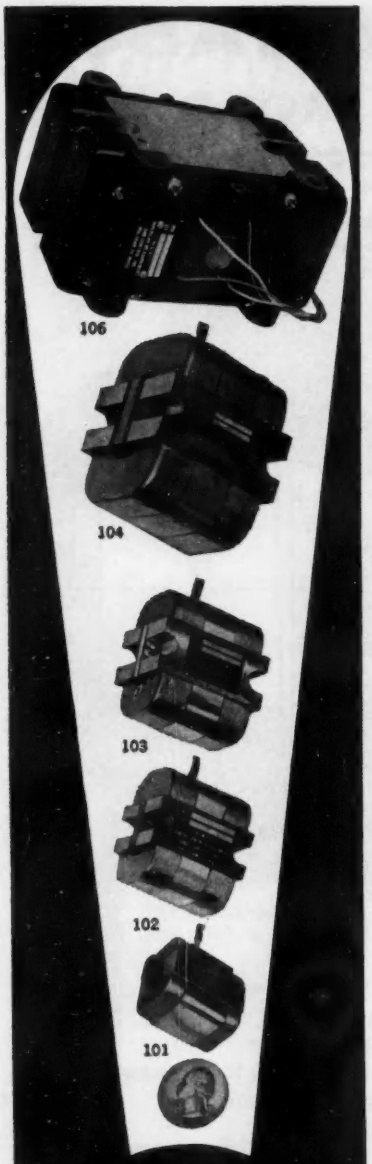

TORQUE MOTORS
FOR SERVO APPLICATIONS

SPECIFICATIONS*

MODEL	101	102	103	104	106
Stroke (in.)	±0.006	±0.007	±0.009	±0.015	±0.020
Stroking Radius (in.)	0.600	0.500	0.750	0.500	1.250
Midposition Force (lbs)	2.5	5.0	8.0	13.0	15.0
Hysteresis (%)	2	2	2	2	2
Resonant Frequency (cps)	950	775	600	400	250
Weight (oz.)	3¼	6	10	22	55

*Rotary output, dry-coil and high temperature models available.

Write on company letterhead for free booklet on Torque Motor Applications to:
AMERICAN MEASUREMENT & CONTROL, INC. TWinbrook 4-6212
240 Calvary St., Waltham 54, Mass.

ABSTRACTS

forming a signal describing the pattern in a manner most convenient for recognition purposes. Two kinds of descriptions are considered: absolute description, permitting restoration of the described object with certain accuracy, and relative description, containing only the features by which a certain object differs from other objects of the same set. The problem of minimizing absolute and relative descriptions is not only still unsolved, but has not even been sufficiently clearly formulated.

Recognition may be by a simultaneous or a stepped-up operation. When the patterns to be recognized are characterized by n features of which any may be either present or absent, then the description of a pattern is an n-digit binary number. In the case of simultaneous recognition, n-digit numbers are compared. In the case of stepped-up recognition, each digit of the binary number is compared step by step, thus operating with one-digit numbers. This leads to machine simplification. The stepped-up method permits descriptions of varying length. However, simultaneous description is more noise-proof.

A to D program compiler

From "Changing from Analog to Digital Programming by Digital Techniques", by M. L. Stein, Univ. of Minnesota, and J. Rose, Convair-Astronautics. Journal of the Association of Computing Machinery, January 1960, pp. 10-23.

A quick and economical way of writing digital computer programs for the solution of problems already set up for analog computation would be welcomed by analog computer users. They could then use a digital computer to check analog solutions or to obtain greater accuracy for selected analog runs. The method which the authors advocate for accomplishing the shift from analog to digital programming consists of having the digital computer itself analyze a description of the analog setup diagram to deduce the differential equations being solved and compile a complete program including input and output for the integration of these equations.

While the entire presentation is general in nature in that no special properties of any particular computing machine are utilized, a computer system based on these ideas is now in operation at Convair-Astronautics. This system accepts as input the

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PULSE
50μ sec. to 90 sec.
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Square, Triangular, Sine
0.01 cps to 2000 cps
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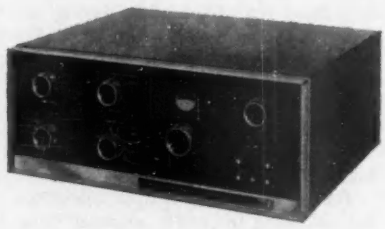

Through unique design, the Parabam Model P-1 Pulse-Waveform Generator provides virtually transient free square, triangular and sine waves plus variable length pulses. Has sufficient output to drive power transistors and relays, electrohydraulic valves and other units directly from the output terminals. *Applications*... test and development of servomechanisms, computers, input-output devices and geophysical equipment.

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SPECIFICATIONS

- Waveforms: Sinusoidal, square and triangular.
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- Pulse amplitude...0 to 60 volts, 200 milliamps max. current.
- Rise/Fall time approx. 2μ sec.
- Cabinet or rack mounted.

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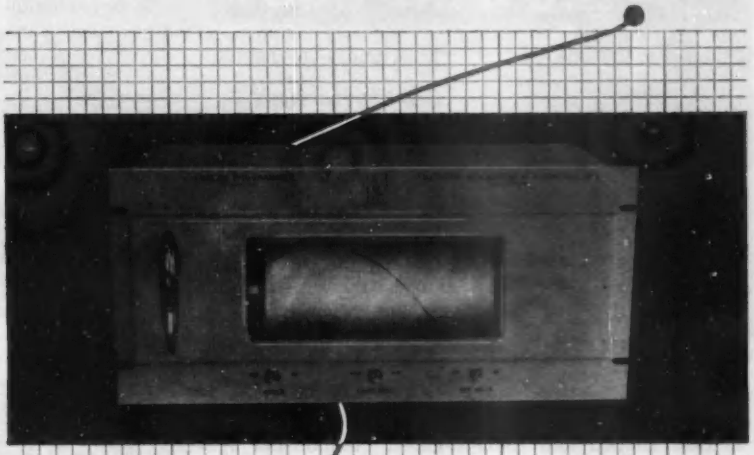

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The Analog Programmer consists basically of a chart-supporting drum and potentiometer roller. A portion of the externally applied potentiometer reference voltage is picked off where the drawn curve intercepts the potentiometer. Thus, at any specific instant of time (X), the output voltage is proportional to the ordinate value (Y) of the drawn curve. Synchronously-motor driven at preselected speeds, an infinite variety of program time conditions are available. Drum can also be servo-motor driven, thus making (X) a function of an independent variable.

Programmer is unequalled in flexibility and convenience for missile flight simulation, structural testing, linear programming of non-linear function, and automatic control of industrial operations and processes. Write for literature.

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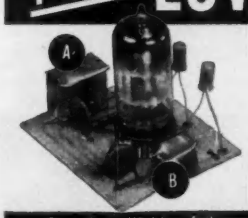

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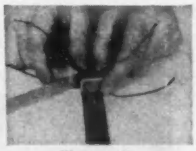
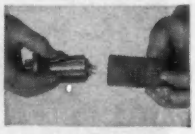

Wraps easily.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Shielding cables reduces magnetic radiation or pickup.

Wrapping tubes prevents outside magnetic interference.

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When accidentally exposed to unpredictable magnetic fields, presto!—your valuable data is combined with confusing signals or even erased.

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MODEL	20-1	20-2	20-3	20-4
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Output Radius (in.)	.650	.593	.750	.906
Midposition Force (lb.)	2.5	5.0	8.0	13.0
Hysteresis (%)	2	2	2	2
Resonant Frequency (CPS)	940	790	580	400
Max. Power Req'd (Watts)	1.6	2.65	3.1	5.2
Weight (oz.)	2.8	5.8	9.0	19.5

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ABSTRACTS

description of a diagram prepared for an Electronic Associates PACE analog computer and produces a program for an IBM 704. It recognizes 18 types of elements and accounts for scale factors and sign reversals. Consequently, most PACE diagrams can be processed with little or no change.

Learning machines

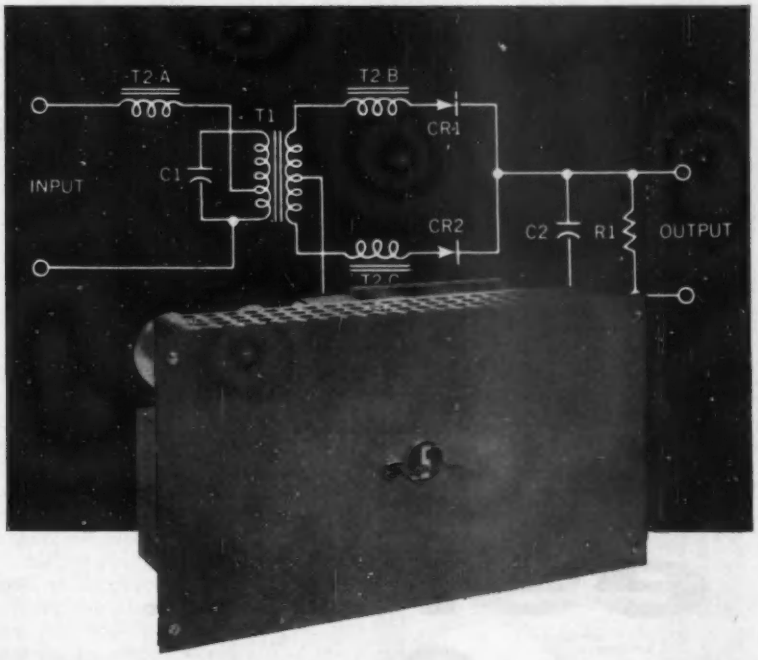
From "Self-Instructional Devices: A Review of Current Concepts", by W. J. Carr, Bucknell University for Wright Air Development Center, U. S. Air Force, Aug. 1959. Now available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. as PB 161339, 29 pp., 75 cents.

This report contains a selective review of literature on self-instructional devices. Emphasis is placed on studies which provide for a functional analysis of these devices. The three major classes of variables which influence learning by self-instructional devices were found to be characteristics of the device, the program, and the learner. Major attention was devoted to an analysis of the process of programming. Variables influencing the effectiveness of programs are discussed. Also described is a working model based on conditioning processes.

Adaptive systems

From "Performance Criteria in Adaptive Control", by C. W. Sarture and J. A. Aseltine, Space Technology Labs. Paper presented at the IRE 7th Region Conference. Seattle, Wash., May 1960.

Adaptive systems have been defined as being characterized by: (1) a means for performance measurement, (2) translation of this measurement into a quantitative figure of merit, (3) closed-loop adjustment of the system parameters by means of the figure of merit. Since Item 2 will be realized through some performance criterion, the latter can be viewed as an essential element of adaptive control. This paper reviews a number of adaptive systems from the point of view of the performance criterion used. Included in the adaptive systems considered are those using the following performance criteria: (1) operation at an extremum, (2) ITAE, (3) impulse response area ratio, (4) step response meeting specified requirements, (5) maximum loop gain with model, (6) mean squared error with model.



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MD 12–4.2	145	MD 12–16.7	215	MD 12–62.5	423
MD 28–1.8	137	MD 28–7.2	184	MD 28–26.8	336
MD 48–1.1	131	MD 48–4.2	179	MD 48–15.7	315
100 watt		400 watt		1500 watt	
MD 6.3–15.9	$194	MD 6.3–63.5	$348	MD 6.3–239	$921
MD 12–8.4	171	MD 12–33.3	292	MD 12–125	735
MD 28–3.6	158	MD 28–14.3	247	MD 28–53.6	567
MD 48–2.1	152	MD 48–8.4	231	MD 48–31.3	525

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An entirely new concept in analog-type computer. Solves intricate system design problems in minutes instead of hours, hours instead of days. Write for descriptive engineering bulletins, ESIAC solutions to system design problems or an ESIAC demonstration in your plant.

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Technical literature outlining the wide range of characteristics available in each type relay is yours for the asking. You'll find "Diamond H" engineers skilled in optimizing the basic designs to meet your specific requirements.

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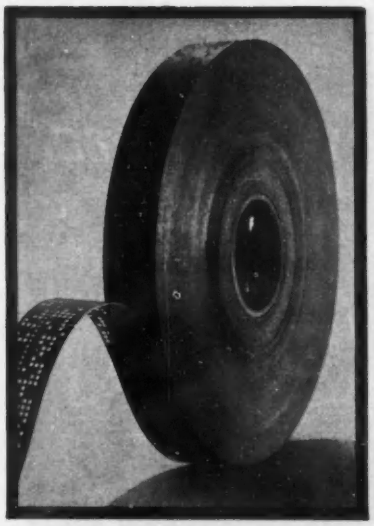

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New "Peerless" Fibre control tape wears 30 times longer than paper; costs 1/6th that of polyester film!

Need a tough tape that will take machine shop handling? A durable tape for repeat operations? Check the savings in new "Peerless" control tape. It's made of National Vulcanized Fibre, a cellulose plastic—the only tape of its kind!

Compare "Peerless" tape's long, cost-cutting cycle life:

Speed (CODES PER MINUTE)	Paper Tape (CYCLES)	"Peerless" (CYCLES)
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620	1200 to 1900	30,000 & over

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"Peerless" does not stretch in use. Precision-punched holes remain true. In addition, "Peerless" is *plastic-smooth* and impurity-free; friction and wear on punching and feeding equipment are cut to the minimum.

"Peerless" tape is available in any width. It is already proving its superior economies in tape life and cost on major automatic programming equipment in industry, government and business. Colors: Red, Gray, Blue, Black. Investigate now. Write for Free test sample and complete information. Dept. PP-8.

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NEW BOOKS

New approach

CONTROL SYSTEM ANALYSIS AND SYNTHESIS. *John J. D'Azzo and C. H. Houpis.* 580 pp. *Published by McGraw-Hill Book Co., Inc., New York, N. Y.* $13.50.

This reviewer's initial reaction when asked to comment on *Control System Analysis and Synthesis* was: "Why another text on control system design?" It seemed that all the fundamentals had been covered adequately by existing books and no real purpose could be served by the publication of still another. However, a closer examination of both its organization and its content indicated that this book is a worthwhile addition to the list of textbooks on feedback control systems.

From the standpoint of organization this book is unique because it presents the root-locus method of analysis before the frequency plots. The authors believe that this shift in emphasis enables their readers to obtain more quickly an understanding and "feel" for control system performance. The authors are to be commended for teaching students to think initially in terms of the entire complex plane, restricting them to the $j\omega$ axis only after familiarization with the concept of poles and zeros.

From the standpoint of content, this book is also unique. First, the authors spend considerable time in developing the differential equations of various dynamic systems. Electric circuits, mechanical systems, hydraulic systems, and even thermal systems are analyzed and their significant parameters discussed. Second, the book devotes a surprisingly generous amount of space to the design of compensation networks. Numerous examples are worked out in detail and clearly show the effects of various types of compensators on a given feedback control system. Third, the book contains many topics not usually discussed in an elementary text: ac carrier systems, optimum response criteria, nonlinearities, and analog computers.

A brief introductory chapter is followed by one on how to describe "the physical laws of nature"; in that chapter are derived the differential equations describing the dynamics of several different physical systems. The following two chapters deal with the solution of these linear differential equations by classical methods and by Laplace transforms. An excellent appendix on methods of factoring polynomials supplements these chap-

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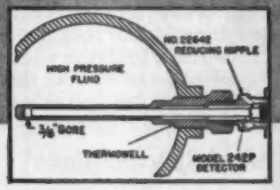
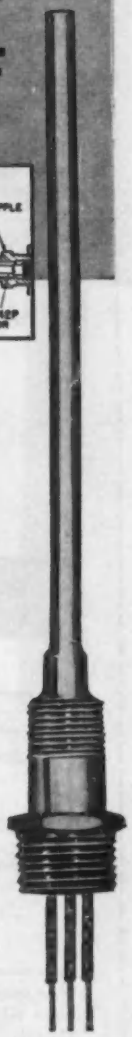
RTD 242P MEASURES FLUID AND GAS TEMPERATURES from −100° to +1500°F



This stem-sensitive Resistance Temperature Detector can be operated in live steam and other high temperature atmospheres up to 1500°F. Widely used in the chemical and petroleum industries, the stainless steel 242P RTD provides readings to 0.01°F. For complete information, write for Reference Data Sheet 1045A-5.



SPECIFICATIONS:

Temperature Resistance Characteristic: No. 8
Time Constant in Agitated Water: 10 sec. approx.
Maximum Current in Air: 0.010 amps; in Water: 0.020 amps
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Engineering notes from the **SM/I REPORTER**

BY STANLEY M. INGERSOLL, *Capabilities Engineer*

Report No. 11
ALC 603 Angle of Attack Computation and Display System

This system embodies engineering experience in angle of attack computational equipment that dates back to 1949. SM/I's Relative Wind Transducers became the first in the industry to satisfy military specifications. Elements of the system are pictured below; a vertical scale or clock-type indicator may be used for visual display. The design of the computer permits numerous variations with minimum modification. In all versions, this sub-system utilizes our Force Balance Mach Number Sensor, noted for its sensitivity and accuracy. As many as four data output servos each employing an SM/I transistorized amplifier can be provided in the unit without altering its exterior configuration. The gear train will operate various combinations of pots, synchros and other output devices. Normally, two SM/I relative wind transducers are used. One measures indicated angle of attack; the other measures angle of side-slip. After Mach number and side-slip corrections are made in the compensator assembly, the output function is the True Angle of Attack.

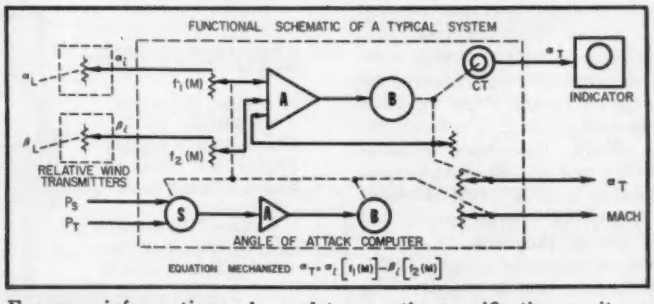
General Specifications

Operating range:
- Angle of Attack ..... 50°
- Angle of Yaw ..... 50°
- Airspeed ..... 200 knots to 600 knots
- Altitude ..... —1000 ft. to 60,000 ft.

Accuracy: ±¼°

Electrical Power Requirements: 115V, 400 cycle @ 2.5 amps (including vane heaters)

Computer Size: 8⅜"x5½"; weight, 7 lbs. (including shock mount)



For more information and complete operating specifications, write or wire SM/I today. Address your inquiry to Stanley M. Ingersoll, Capabilities Engineer.

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Special eddy current damping gives flat response

The MB Vibramite is the only damped vibration pickup available with a flat response curve over its entire operating range.

Other highly desirable features include extremely small size, light weight and omnidirectional use.

Check these specifications:

Frequency range	20-2000 cps
Sensitivity	96.3 mv/in/sec. (Calibrated ±1% at 100 cps into 2 megohm load at 80°F)
Size	1" x 1.42"
Weight	2.75 oz
Natural frequency	15 cps
Damping	Eddy current (nominal .65 of critical)
Acceleration output limit	50 g maximum (minimum limited only by recording equipment)
Max. shock without damage	1000 g

Complete technical details in Bulletin 112A. Write . . .

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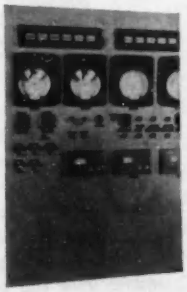

Send blueprints or performance sheets, or request a field engineer to visit your plant to discuss your problem — no cost or obligation, of course.

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ters admirably. Especially worthwhile is the inclusion of the root-solving tables of Luke and Ufford, basically an extension of Lin's method that permits simultaneous solution for all the roots of a polynomial equation.

A discussion of block diagrams and transfer functions is followed by a cursory treatment of basic servo characteristics. In this reviewer's opinion the authors were remiss in not calling their readers' attention to the modern concept of dynamic error coefficients —even a footnote would have sufficed. Instead they limit their discussion to static error coefficients, certainly of relatively less importance today. The next three chapters deal respectively with root-locus, frequency response, and Nyquist's stability criterion.

Then come five excellent chapters on servo design. They run from such elementary topics as gain adjustment by use of *M*-circles to feedback compensation by root-locus methods. These chapters are replete with numerical examples that illustrate various compensation schemes for control systems. Many different types of control systems are used in the examples. As a result these five chapters constitute a self-contained dictionary of compensation techniques.

The next chapter is on multiple loop systems with several inputs. The authors employ block diagram manipulations to simplify multiloop systems having only one input; an appendix contains a supplementary list of useful block diagram transformations. For multiple input systems the authors describe the conditional feedback scheme of Lang and Ham and also present a synthesis technique originated by Povejsil and Fuchs. It is surprising that no mention was made of Freeman's general solution of the synthesis problem, which considers the general case of multiple inputs and multiple outputs.

The remaining chapters cover the following topics: optimum response criteria, nonlinearities and describing functions, analog computers, and experimental and design procedures. There are several useful appendixes in addition to those previously mentioned. Of special interest: use of the Spirule, phase-angle loci, and automatic root-locus plotting.

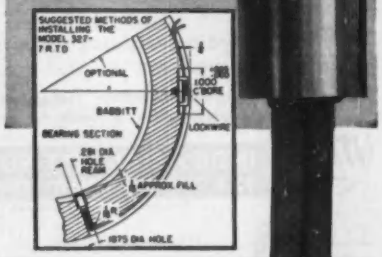
In summary this book is an excellent text for a first course in servomechanism theory and an equally excellent reference for the practicing engineer.

Leslie R. Axelrod
The Powers Regulator Company

EDISON

MINIATURE RTD 327-7 MEASURES PRECISE TEMPERATURES from −70° to +450°F

(3 times actual size)



This miniature tip-sensitive Resistance Temperature Detector has its sensing element located within .060" of tip for fast response to temperature changes. Small size enables it to be installed where larger types of temperature sensing elements would not fit. It may be mounted from inside of bearing and its tip is tinned so that it may easily be covered with babbitt after installation. Use with terminal 41820. For complete information, write for Reference Data Sheet 1045A-9.

SPECIFICATIONS:

Temperature Resistance Characteristic: No. 7
Time Constant in Water: 4.0 sec.
Maximum Current in Bearing: 0.015 amps
Maximum Pressure: 2500 psi in babbitt installation

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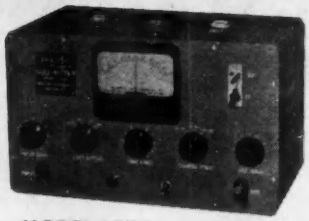

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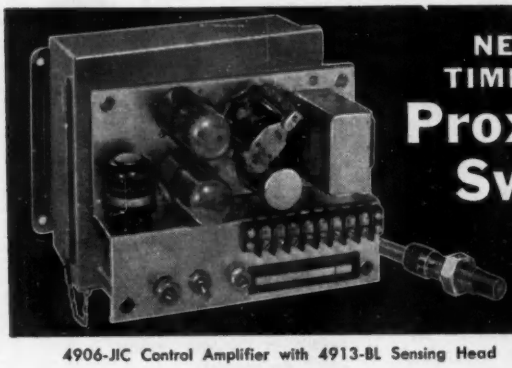

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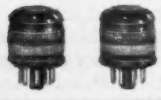

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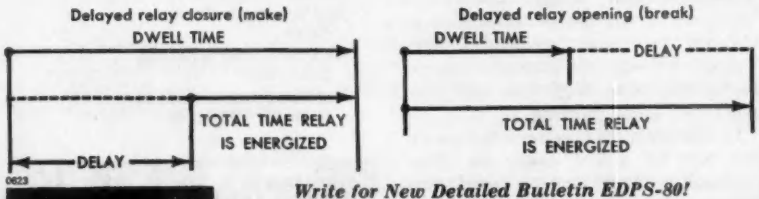

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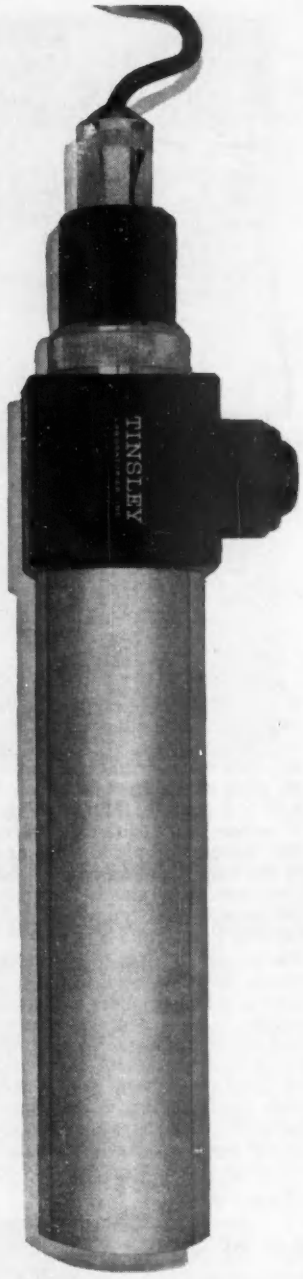

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MEETINGS

SEPTEMBER

Society of Instrument Technology and the British Interplanetary Society, Symposium on Rocket and Satellite Instrumentation, London, England Sept. 1

Production Engineering Show, Navy Pier, Chicago, Ill. Sept. 6-16

National Machine Tool Builders Association, Machine Tool Exposition (in connection with Production Engineering Show), International Amphitheatre, Chicago, Ill. Sept. 6-16

Joint Automatic Control Conference, sponsored by ASME, AIEE, IRE, ISA, and AIChE, Massachusetts Institute of Technology, Cambridge, Mass. Sept. 7-9

Second Coliseum Machinery Show, Chicago Coliseum, Chicago, Ill. Sept. 7-15

American Society of Mechanical Engineers, Engineering Management Conference, Hotel Morrison, Chicago, Ill. Sept. 15-16

International Symposium on Data Transmission, sponsored by IRE, Benelux section, (conducted in English), Technische Hogeschool, Delft, Netherlands Sept. 19-21

Institute of Radio Engineers, National Symposium on Space Electronics and Telemetry, Shoreham Hotel, Washington, D. C. Sept. 19-22

American Institute of Electrical Engineers, Ninth Annual Industrial Electronics Symposium, Sheraton Cleveland Hotel, Cleveland, Ohio Sept. 21-22

American Society of Mechanical Engineers, Power Conference, Bellevue-Stratford Hotel, Philadelphia, Pa. Sept. 21-23

Instrument Society of America, 15th Annual Instrument-Automation Conference and Exhibit, New York Coliseum, New York, N. Y. Sept. 26-30

American Rocket Society, Space Power Systems Conference, Miramar Hotel, Santa Monica, Calif. Sept. 27-30

OCTOBER

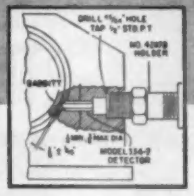
American Institute of Electrical Engineers, Fall General Meeting, Morrison Hotel, Chicago, Ill. Oct. 9-14

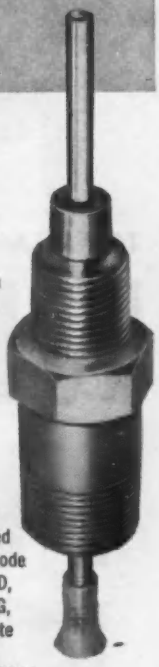
National Electronics Conference, Hotel Sherman, Chicago, Ill. Oct. 10-12

Institute of Radio Engineers, Sym-

EDISON

RTD 334-7 MEASURES BEARING TEMPERATURES IN EXPLOSIVE ATMOSPHERES from −70° to +500°F





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SPECIFICATIONS:

Temperature Resistance Characteristic: No. 7
Time Constant in Agitated Water: 2 sec.
Maximum Current in Air: .015 amps; in Water: .025 amps.
Maximum Pressure: 200 psi

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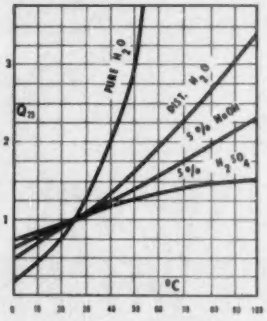
A prime requisite for high accuracy in conductivity measurements is a good match between the temperature coefficient of conductivity of the solution under test, and the characteristics of the temperature compensator. A small departure multiplied by a large number of °F can produce an impressively large error.



The above curve demonstrates the extent to which the temperature-conductivity characteristics of four common solutions differ from each other. Q_{25}, shown as the vertical coordinate, is the ratio of the conductivity of a solution at t°C to the conductivity of the same solution at 25°C. A temperature compensator designed to match any **one** of these solutions would fail miserably if used for any of the others.

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MEETINGS

posium on Adaptive Control Systems, Garden City Hotel, Garden City, N. Y. Oct. 17-19

American Society for Metals, 42nd National Metal Exposition and Congress, Trade and Convention Center, Philadelphia, Pa. Oct. 17-21

Second International Congress and Exhibition for Measuring Techniques and Automation (INTERKAMA), Dusseldorf, Germany Oct. 19-26

Institute of Management Sciences, Seventh International Meeting, session on computers and simulation techniques, Hotel Roosevelt, New York City. Oct. 20-22

Institute of Radio Engineers, East Coast Aeronautical and Navigational Electronics Conference, Lord Baltimore Hotel, Baltimore, Md. Oct. 24-26

Fifth Annual Conference on Non-Linear Magnetics and Magnetic Amplifiers, sponsored by IRE and AIEE, Bellevue-Stratford, Philadelphia, Pa. Oct 26-28

Institute of Radio Engineers, Electron Devices Meeting, Shoreham Hotel, Washington, D. C. Oct. 27-28

NOVEMBER

Institute of Radio Engineers, 13th Annual Conference on Electrical Techniques in Medicine and Biology, Theme: application of electronic techniques to analytical instrumentation, Sheraton-Park Hotel, Washington, D. C. Nov. 1-2

Sixth Annual Conference on Magnetism and Magnetic Materials, sponsored by AIEE and American Institute of Physics, New Yorker Hotel, New York, N. Y. Nov. 14-17

Symposium on Engineering Applications of Probability and Random Function Theory, Purdue University, Lafayette, Ind. Nov. 15-16

Institute of Radio Engineers, Mid-America Electronics Convention (MAECON), Hotel Muehlebach, Kansas City, Mo. Nov 15-16

American Society of Mechanical Engineers, Annual Meeting, Statler Hilton Hotel, New York, N. Y. Nov. 27-Dec. 2

DECEMBER

Eastern Joint Computer Conference, sponsored by IRE, AIEE, ACM, Hotel New Yorker and the Manhattan Center, New York, N. Y. Dec. 13-15

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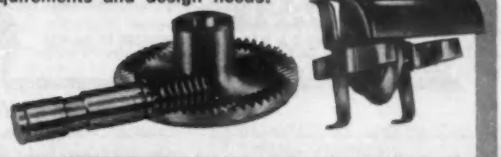

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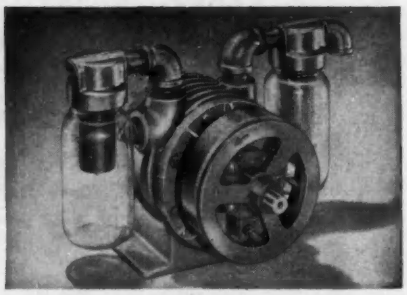

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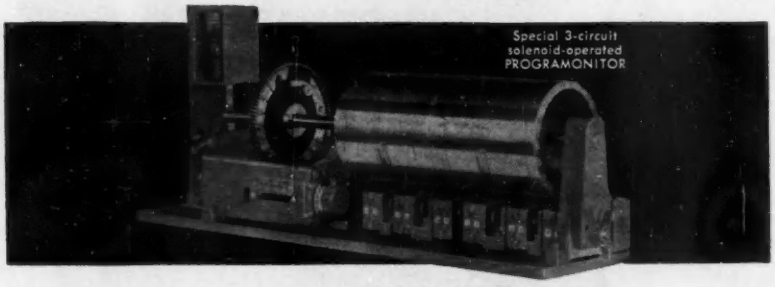

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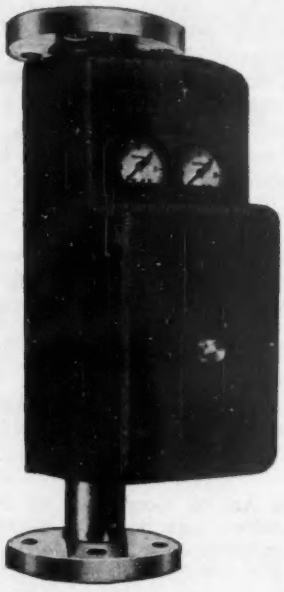

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WHAT'S AVAILABLE IN REPRINTS

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504—**System Characteristics of Modern Guidance Techniques,** August 1960, 22 pp. In this special report five experts from three companies cover the system characteristics of inertial navigators, guidance radars, Doppler radar techniques, modern techniques in celestial navigation, and perceptive guidance systems. 65 cents.

503—**How to Determine Stream Analyzer Dynamics,** 8 pp. This package of two articles shows how analyzers can introduce dynamic errors, how to determine analyzer dynamics, and how to improve performance. The instrument used is a differential refractometer but techniques can be extrapolated to other types of analyzers. 40 cents.

502—**Survey of Dynamic Display Techniques,** 20 pp. The function of these newly developed techniques is to put up-to-date information in the hands of human operators of control systems when the information changes at a high rate. Both basic approaches and commercial hardware are discussed for cathode ray tube displays, optical systems, and miscellaneous devices ranging from TV pickup to matrix cells. 50 cents.

501—**Six Transducers for Precision Position Measurement,** May 1960, 6 pp. Explains operation and gives practical application hints for six precision position transducers: pin-and-pawl mechanism, magnetic bench-mark system, resolver-type transducer, electrostatic transducer, coded-disc devices, and diffraction gratings. 30 cents.

500—**Ready Reference Data Files—I, II, III,** 76 pp. The feature here is a special rate for those who purchase all of the Data Files published in CONTROL ENGINEERING through April 1960. The 36 articles included in this package cover analysis, design, and application short-cuts for all phases of the control field. Everyone can use this timeless reference material. $1.35.

499—**Ready Reference Data Files—III,** 28 pp. Includes the third dozen Data Files published in CONTROL ENGINEERING. Topics range from control of metal

Continued on page 284

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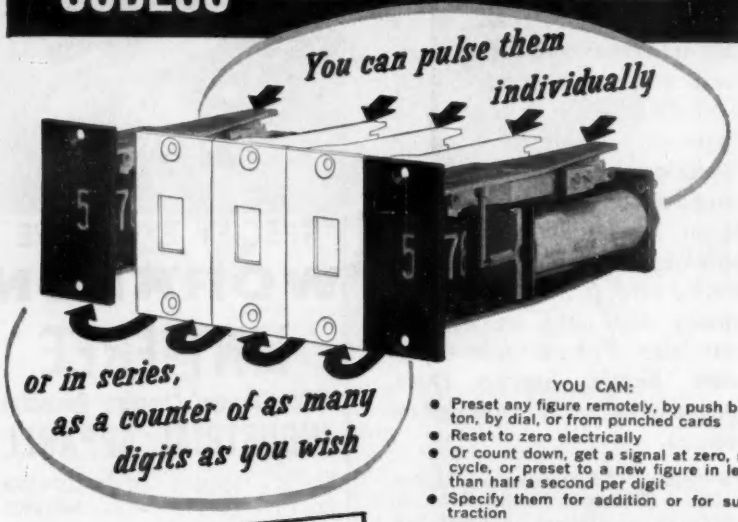

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Continued on page 286

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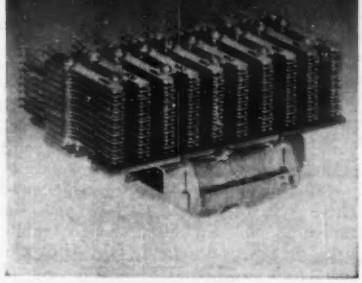

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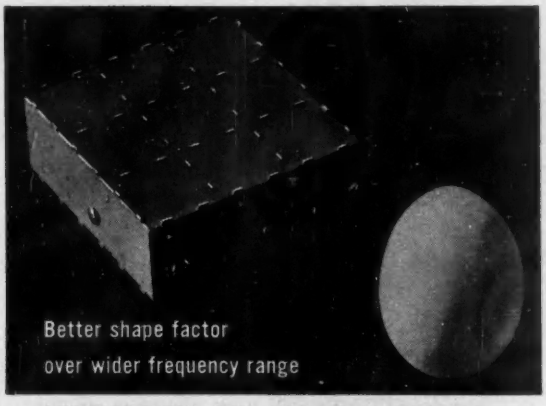

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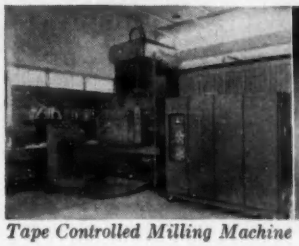

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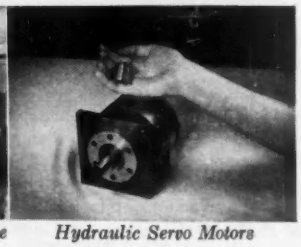

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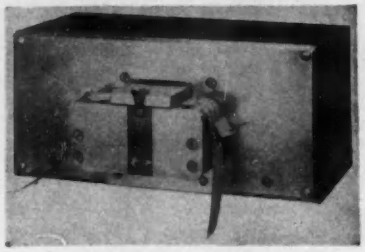

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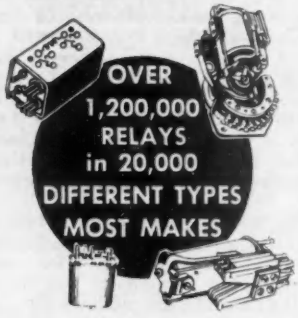

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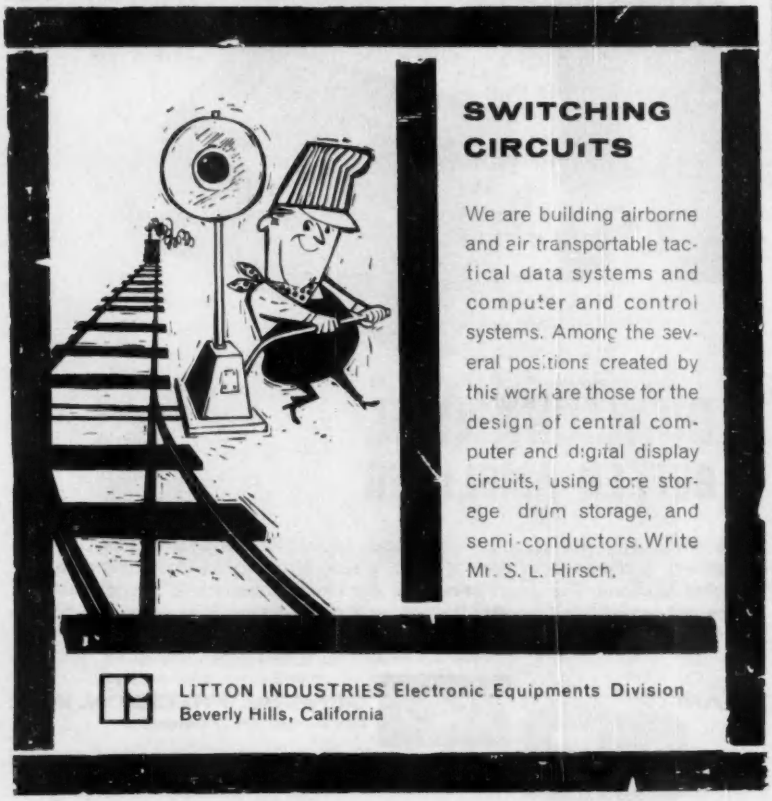

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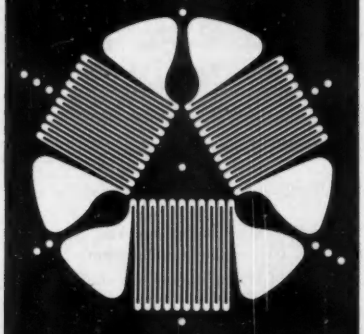

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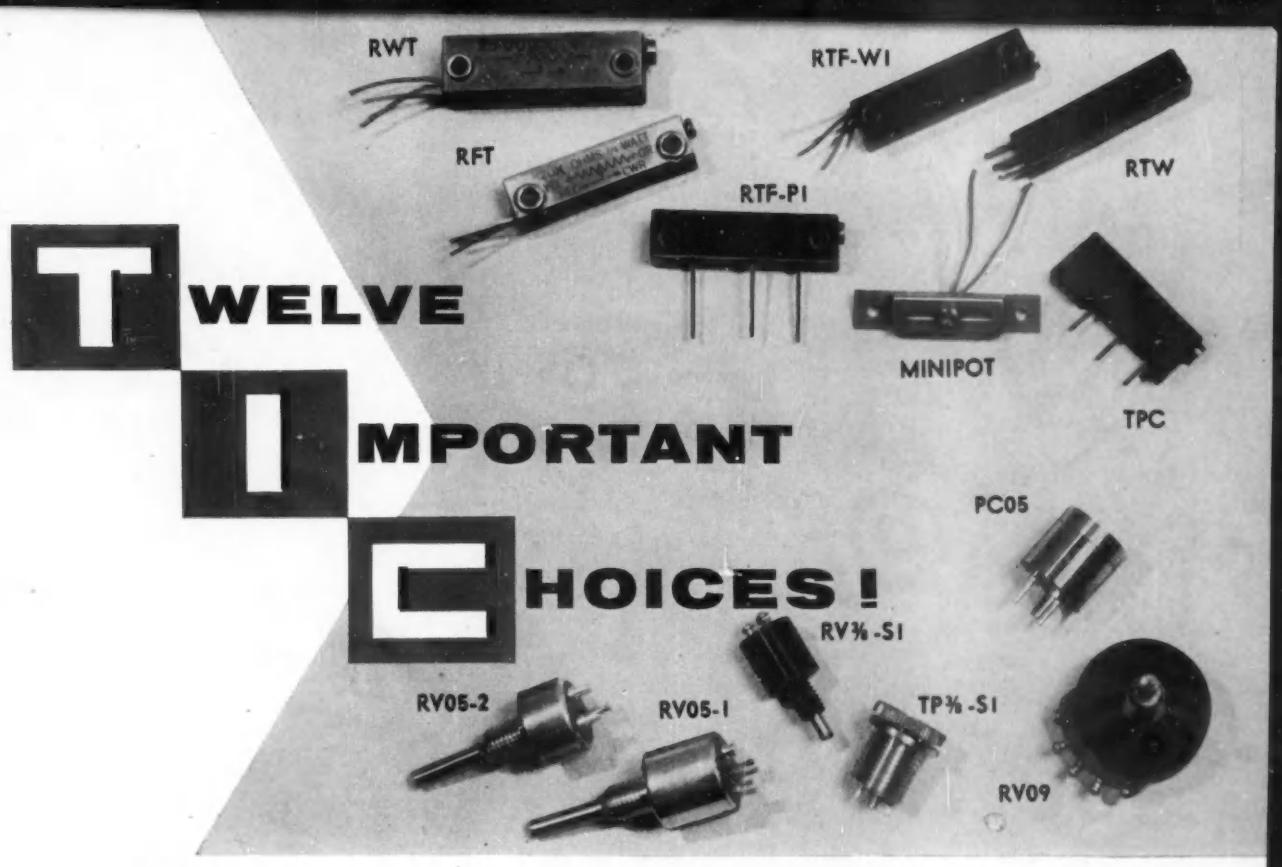

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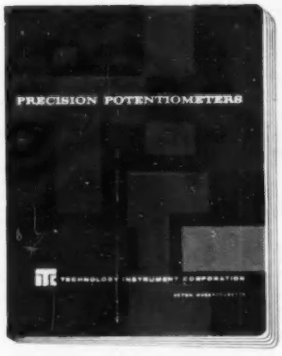

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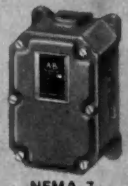

NEMA 7

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11-60-M

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